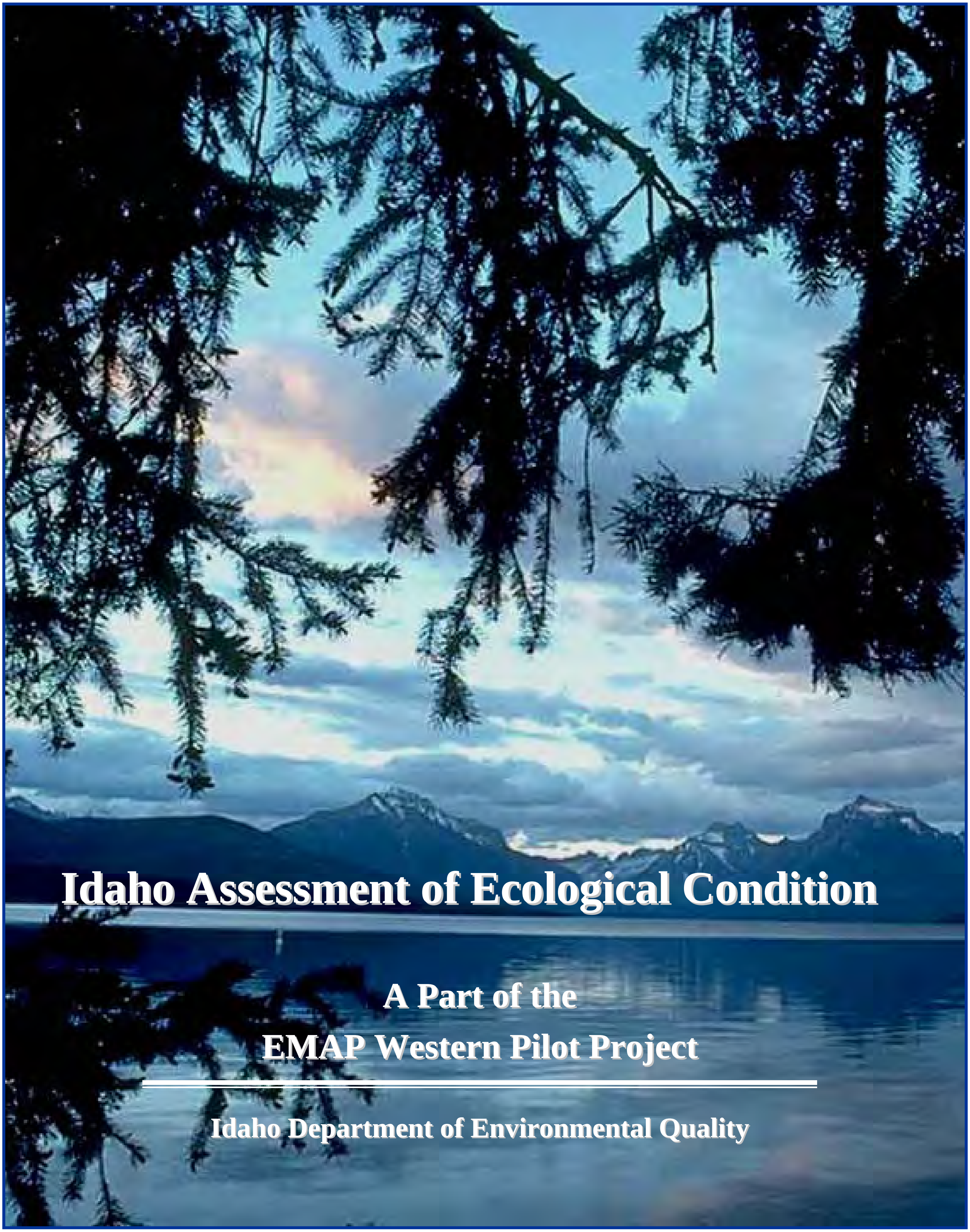

Idaho Assessment of Ecological Condition

A Part of the
EMAP Western Pilot Project

Idaho Department of Environmental Quality

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Idaho Assessment of Ecological Condition

May 2008

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Executive Summary

The Clean Water Act directs the U.S. Environmental Protection Agency (EPA) to describe the condition of the waters in the U.S. Questions posed to the EPA include: What is the overall condition of the nation's waters, what range of conditions are found in the nation's waters, and is this condition improving or deteriorating? Additionally, what human activities are affecting streams and rivers, and which are likely to be the most important? Although various attempts have been made, these seemingly simple questions have not been answered in a truly reliable way in the past 30 years. This report presents Idaho's portion of the unique collaboration between the U.S. Environmental Protection Agency and twelve western States, designed to answer these questions for the rivers and streams of the West.

The EMAP-Western pilot project (EMAP -West) is the largest monitoring and assessment effort designed to answer these questions that has been conducted to date. For EMAP-West, twelve western States and EPA collected chemical, physical, and biological data at more than 1,340 perennial stream and river locations to assess the ecological condition of western waters and the most important factors affecting that condition. In partnership with the States and EPA Regions 8, 9 and 10, the EMAP program sent teams to collect samples at sites chosen by an innovative probability design that insures results will be statistically representative of the entire population of streams in the west. From 2000 to 2004, Idaho sampled 48 stream sites and 47 river sites selected by probability design, as well as 19 hand-picked reference stream sites using EPA's sampling protocols. This sampling effort resulted in a better understanding of the overall condition of Idaho's perennial streams and rivers.

This information fills an important gap in meeting requirements of the Clean Water Act. The questions answered in this report include:

- What is the overall estimated ecological condition of wadeable perennial streams in Idaho?
- Are the indicators selected useful in assessing impacts from habitat alteration to the riparian ecosystem?
- How site assessments using the EMAP monitoring protocols compare with site assessments using Idaho's Beneficial Use Reconnaissance Program (BURP) monitoring protocols?
- What is the overall estimated ecological condition of non-wadeable rivers in Idaho?

Idaho's portion of these surveys results show that the ecological condition of the State's streams and rivers is relatively good, however, there are areas of statistical difference. In the Mountain region, 52% of the stream length has Good physical habitat, 44% have chemical concentrations better than the 25th percentile of reference sites, 68% have Good macroinvertebrate community integrity and 81% show little or no macroinvertebrate taxa loss. There is a significant difference in the Xeric region, however, where only 37% of the stream miles are rated Good for physical habitat, 29% Good for chemistry, 66% for macroinvertebrate community integrity and only 66% show little or no macroinvertebrate taxa loss.

The results also appear to indicate that the most likely factor for diminished biological quality in flowing waters is disturbance of riparian habitat. Evaluation of the stressors most likely responsible for poor condition is best understood by looking at both the extent of each stressor (i.e., how widespread it is) and the relative risk posed to aquatic biota when a specific stressor is present. High phosphorus concentrations are found in over 1/3 of Idaho streams, and macroinvertebrate communities are three times as likely to be in poor condition when phosphorus exceeds a critical threshold versus when it is below these critical values. From a management point of view, the highest priority stressors to address are those that are both common and those pose a high risk to biota.

Results reported here suggest that the Mountain region is more susceptible to riparian disturbance from agriculture and other human activities. Streams in the Xeric region are more likely affected by chemical stressors such as sulfates and total phosphorus.

Organization of this Report

In this report, results are presented for three different projects. The first section details the results of the Idaho Statewide Assessment of EMAP sites and addresses the points outlined in the first and second questions. The second section is a detailed comparison of Idaho Department of Environmental Quality's wadeable stream (BURP) monitoring protocols to EPA's (EMAP) monitoring protocols and addresses the third question. The last section is an assessment of the regional EMAP large and medium rivers study and addresses the last question.

A. EMAP-West in Idaho

Mary Anne Kosterman, Idaho Department of Environmental Quality

A.1. Introduction

A.1.1. Purpose

The purpose of this report is to describe the overall estimated condition of flowing perennial waters within the State of Idaho as monitored during the Environmental Monitoring and Assessment Program (EMAP) Western pilot project (EMAP - West) from 2001 through 2004. This report answers the following questions:

- What is the overall estimated ecological condition of wadeable perennial streams in Idaho?
- Are the indicators selected useful in assessing impacts from habitat alteration to the riparian ecosystem?

A.1.2. Background

The Clean Water Act directs the U.S. Environmental Protection Agency (EPA) and States to develop programs that evaluate, restore, and maintain the chemical, physical, and biological integrity of the Nation's waters (1987). State agencies are conducting biological assessments in the Northwest to provide the information necessary to develop biological criteria. Biological criteria can complement existing physical and chemical water quality criteria and provide a better understanding of and more protection for the nation’s aquatic resources. EMAP was initiated by EPA's Office of Research and Development (ORD) to estimate the current status and trends in the condition of the nation's ecological resources including streams and rivers (Hughes et al. 2000; Paulsen et al. 1991). In addition, EMAP examines the relative associations between indicators of ecological condition and stressors from natural and anthropogenic sources.

A.1.3. EMAP-West

EMAP-West was a five-year effort to collect stream and river data throughout a twelve-state area, including Idaho. This area is represented by the portions of EPA Regions 8, 9, and 10 that are within the conterminous United States. Consistent methods were employed across the area and across stream sizes. This allowed one four-person crew to collect data on vertebrate, macroinvertebrate, and algal assemblages, physical and chemical habitat, invasive riparian plant species, and fish tissue, in a single day (Peck et al. 2005a; Peck et al. 2005b).

There are three components of EMAP-West, one of which is Surface Waters (the others are Coastal Waters and Landscapes). In EPA Region 10, the Surface Waters component was designed to evaluate the ecological condition of streams and rivers and identify stressors associated with impairments of these systems at two scales. One scale is the broad Regional and State level, which allows evaluation of the overall condition of streams by state. The second scale is a smaller localized level based on Region 10's desire to better characterize the ecological conditions of streams and rivers in three focused geographic areas or resource types. These areas of intensification were sampled over the same period as the broad scale sample sites.

A.1.4. Probability-based Design

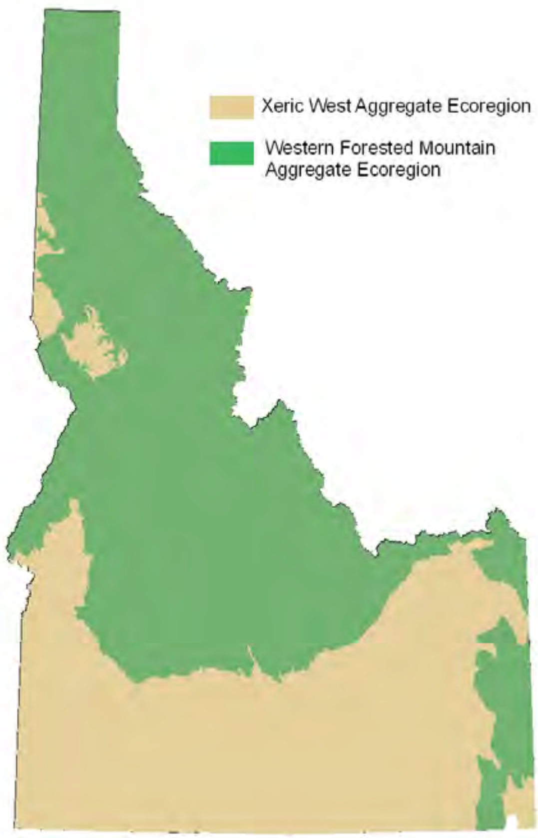
One aspect of EMAP is the use of probability-based design. In EMAP-West, monitoring sites were chosen according to a probability-based sampling design, in which each site has a known probability of being selected for sampling, and as a group the sites statistically represent the population of flowing waters in the region. EMAP's probability-based design applies the statistical rigor of sample surveys to the science of environmental assessment (Diaz-Ramos et al. 1996). Throughout this report, sites chosen by the probability design process are referred to as random sites since they are selected at random and will be able to statistically represent the population as a whole. This report's References section (page 71) contains bibliographic information for several additional sources of information about probability-based design (Olsen et al. 1999; Stevens Jr., D 1997; Stevens Jr., D. et al. 2000).

A.1.5. EMAP-West Special Interest Area in Idaho

Within the framework established by the national EMAP, a partnership was formed between ORD, Region 10, and Idaho to apply EMAP approaches to a smaller geographic scale. This partnership was called Regional EMAP (R-EMAP) and had two major features in common with the national EMAP study. These were a probability-based sampling design and the use of ecological indicators. Idaho chose to focus on medium and large rivers for this regional study and collected fish, periphyton, and macroinvertebrate assemblage samples as well as parameters for physical habitat and selected water column chemistry (Olsen 2002). This report will detail the results of that regional work as well.

Water is scarce in the West and rapid population and land use changes challenge water quality managers as various users compete for access to this limited resource. Idaho's rivers and streams are valued for their scenic beauty (e.g., the Main Salmon River, Middle Fork Salmon River and Selway/Lochsa Rivers), their biological resources (e.g., salmon and steelhead), and their capacity to generate electrical power and supply irrigation water, and managers must consider all these uses. There are over 111,000 miles (179,000 kilometers) of streams traversing a range of ecological conditions from lowland desert to high alpine mountain in Idaho while land use is equally divided between forested and rangeland (42% each) with 16% of total land area in agricultural use. These uses significantly influence the status and condition of aquatic resources through hydrologic modifications, habitat alterations, and other nonpoint source impacts. This report summarizes the ecological impacts to streams and rivers across the state where impairments are primarily due to nonpoint sources.

Figure 1: Level III Aggregate Ecoregions in Idaho (Appendix C). Specific details of the EMAP-West design, as well as more detailed information on data, indicators, and analyses used in this report, can be found in the EMAP-West statistical summary (Stoddard et al. 2005).



A.2. Description

Generally, there are two ways to obtain information about the aquatic environment. The most common approach has been to collect information at locations chosen for a variety of factors. These factors could include access and ease of sampling, areas of special interest, whether certain areas are thought to be representative, etc. With this approach, the interpretation of the sampling results relies on best professional judgment, or in some cases mathematical modeling, to address the questions of interest. Sites chosen in this manner are typically viewed to be representative of the stream as a whole in the best professional judgment of the sampling technician; therefore, the assessment results should be applicable to the entire stream length. The other approach focuses on a statistical methodology that can provide information about the aquatic resource as a whole. Statistically based approaches employ scientific methodology developed for surveys to provide quantitative answers and uncertainty measures for the sampled resource (Olsen et al. 1999). One advantage of the statistically based designs is that sampling results can be applied to the entire aquatic resource instead of one stream. EMAP Sites were selected using a probability design stratified to allow national, regional, and statewide assessments.

A.2.1. Aggregated Ecoregions

There are ten Level III ecoregions (Omernik 1987) found in Idaho. However, in order to adequately describe all ecoregions, a total of 500 sites would need to be monitored and evaluated (50 within each ecoregion). Therefore, the Level III ecoregions were aggregated into two predominant ecoregions, the Western Forested Mountains (Mountainous) and the Xeric West (Xeric), shown on the map in Figure 1. Table 1 details which Level III ecoregions were aggregated. Generally speaking, grouping ecoregions into these predominant ecoregional aggregates is fairly representative of Idaho. Mountain ecoregions were combined because they typically have similar land uses, precipitation, and geology. Basin and plains ecoregions were combined into the Xeric ecoregion for similar reasons. The Mountain ecoregion is higher and steeper with numerous perennial streams and typically more precipitation and vegetation. Forestry-related land uses are common in this ecoregion. The Xeric ecoregion has lower and gentler slopes with a drier climate and more streams that stop flowing seasonally. Within the Xeric ecoregion, agriculture is common in the valleys and river plains, while grazing is common in the upland areas.

Table 1: Aggregate ecoregions used in data analysis.

Aggregate Ecoregion Name	Level III Ecoregion	Ecoregion Name	Number of sites
Western Forested Mountains	11	Blue Mountains	3
	15	Northern Rockies	12
	16	Idaho Batholith	20
	17	Middle Rockies	6
	19	Wasatch and Uinta Mountains	1
Xeric West	10	Columbia Plateau	1
	12	Snake River Basin	0
	13	Central Basin and Range	0
	18	Wyoming Basin	0
	80	Northern Basin and Range	5

A.2.2. Probability-based Design

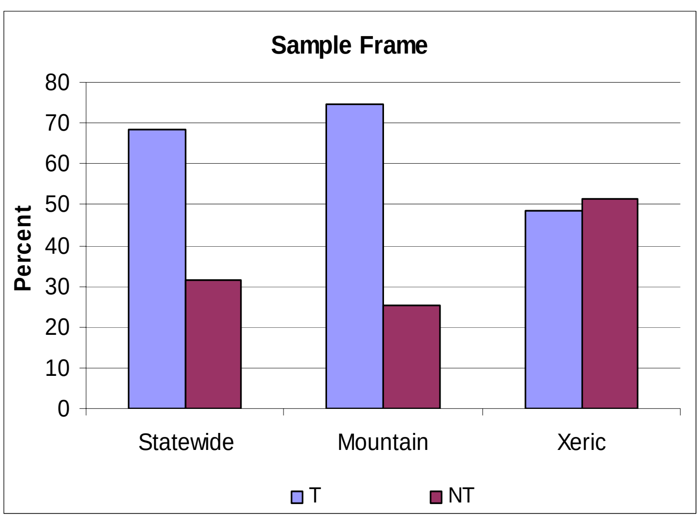
A target population is a specific resource set targeted for investigation, and must be clearly defined. In the case of the EMAP-West design, the target population was defined as all perennial streams found in EPA's River Reach File (RF3), a digitized version of 1:100,000 scale USGS topographic maps (Hall et al. 2000). The RF3 file used to generate the sampling frame (the physical representation of the target population) shows more than 111,000 miles (179,000 km) of perennial streams in Idaho. Sites were determined to be either target or non-target (i.e., part of the target population or not) (Figure 2). Sites determined to be non-target include sites on non-perennial streams, in reservoirs, wetlands, or irrigation canals, or otherwise not on an active stream channel (Olsen et al. 1999). In all, 138 sites were evaluated, 97 were included as part of the target population and 41 were non-target. This means that 30% of the sites were found to be non-target as shown in Figure 2 and that in the RF3 file for Idaho 30% of the digitized streams are non-perennial and may actually be reservoirs, wetlands, irrigation canals, inactive or dry stream channels.

The EMAP probability design is based on a systematic grid layered over landscape maps (Herlihy et al. 2000). Each intersection of the grid that occupies the same location as a wadeable stream becomes a potential stream sampling location. A subset of that population is selected as potential monitoring sites. When the EMAP probability design was first applied to Idaho, sites were located only in the Mountain ecoregion where more stream miles exist than in the Xeric ecoregion. The probability design had to be re-weighted in order to select some xeric sites and maintain spatial integrity in the probability design for comparison purposes. In all, forty-eight (48) random sites were monitored from 2000 through 2003. Of those 48 sites, forty-two (42) were located in the Mountain ecoregion and six (6) in the Xeric ecoregion and represent the number of stream miles shown in Table 2. Additionally, nineteen (19) other sites were hand selected as reference sites for index development using best professional judgment. These 19 reference sites were sampled in 2004.

Table 2: Miles of Stream in each Aggregate Ecoregion.

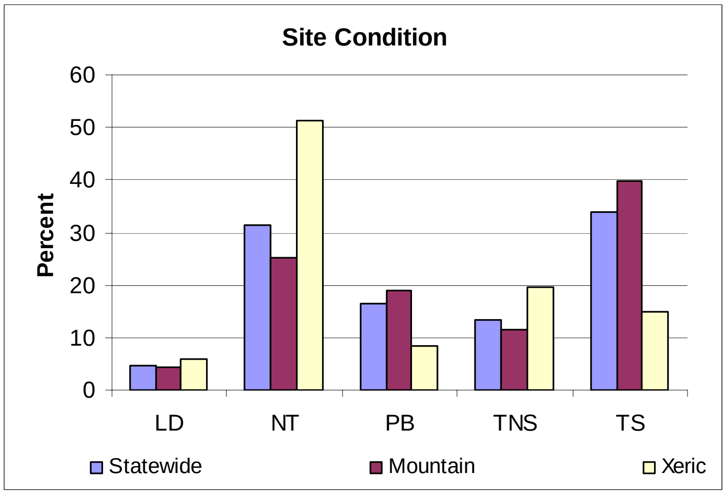
Stream Miles represented:					
	Total Miles	Miles in Target Population	Miles in Non-target Population	Number of Sites	Miles/site
Mountain Ecoregion	58058	43371 (75%)	14687 (25%)	42	1032.654
Xeric Ecoregion	38276	18612 (49%)	19664 (51%)	6	3102.058
Total	96334	61984 (68%)	34350 (32%)	48	

Figure 2: Target population of EMAP sites selected using probability design with percent of stream length defined as target (T) and non-target (NT).



Of the 97 sites evaluated as target sites that were part of the sampling frame, 48 were monitored over the course of 4 years. Due to various factors including landowner access denial, inaccessibility, dry channel and map error, 49 sites that were target sites were not sampled. A complete breakdown of the total number of sites evaluated (138), the number of target sampled sites (48) and sites that were not sampled (49) is shown in Figure 3.

Figure 3: Percent of stream length for key categories in Idaho, including Landowner Denied Access (LD), Non-target (NT), Inaccessible (PB), Target Not Sampled (TNS) and Target Sampled (TS).



A.2.3. Indicators of Ecological Conditions

EMAP-West uses indicators to measure the chemical, physical, and biological condition of wadeable streams. These indicators measure characteristics of the environment and the overall ecological integrity of a stream. Biological communities reflect the chemical, physical, and biological condition of a stream, thereby fulfilling the primary goal of the Clean Water Act to protect biological integrity (Cullen et al. 1999).

Biological integrity is the main focus because the biological community can reflect the cumulative effects of chemical and physical stressors over time; therefore, an assessment of biological integrity implies similar conclusions about chemical and physical integrity. Biological integrity is "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a composition and diversity comparable to that of the natural habitats of the region" (Frey 1977). The main goals of water quality standards are to designate the uses to be made of the water (such as cold water aquatic life or primary contact recreation), to set criteria for protecting those uses, and to prevent degradation of water quality. To assess water quality, the State must measure chemical, physical and biological data on water bodies. To estimate the biological condition of streams and rivers, the composition and relative abundance of key biotic assemblages is analyzed. This report focuses on macroinvertebrates as a surrogate for ecological condition by evaluating two widely used indicators of macroinvertebrate conditions. These indicators are a multi-metric Index of Biotic Integrity (MMI) and the observed/expected ratio (O/E) of taxa loss, both of which of are described in the following section.

A.2.3.1. Macroinvertebrate Condition Indicators

Macroinvertebrates are animals without backbones large enough to be seen with the naked eye. Benthic macroinvertebrates live in or on the substrate of streams and have been used for decades as an indicator of biological integrity. These macroinvertebrates are useful for indicating the condition of the stream because their life cycles may be a year or more with very limited ranges. A long term or recurring episodic pollution problem in the stream may be indicated if a significant number of pollution-tolerant species are present and pollution-sensitive species are missing. Since different types of macroinvertebrates react differently to a wide array of pollutants, it is possible to observe them and thereby determine whether certain types of stress, including specific pollutants, are affecting the community (Snyder et al. 1999).

Macroinvertebrate Multi-metric Index (MMI)

Characteristics of the macroinvertebrate community are often measured and combined to form an index that describes the various niches a macroinvertebrate community fills. These characteristics include taxonomic composition, diversity, richness, feeding groups, habits, and pollution tolerance. For the macroinvertebrate multi-metric index (MMI) reported here, a different specific metric was chosen for each of the characteristics and the measured value for each characteristic was scored against the expected value for the stream (based on reference sites). The final scores for each metric were then combined to create an overall MMI with values ranging from 0 to 100. Further explanation of the metrics used to create the MMI are detailed in the EMAP-West statistical summary (Stoddard et al. 2005).

Macroinvertebrate Observed/Expected (O/E) Ratio of Taxa Loss

Another way to measure the benthic macroinvertebrate community is to evaluate the loss of taxa (Wright 2000). The ratio of observed taxa to expected taxa (O/E) compares the number of macroinvertebrate taxa observed at a site to the number of taxa expected and was developed as a direct measure of how many taxa are missing from a site (Hawkins 2005; Hawkins et al. 2000). The values of O/E range between 0 and 1 (occasionally slightly greater than 1) and indicate variation from taxa expected, which usually means taxa have been lost. For example, an O/E score of 0.75 indicates that three quarters of the expected taxa were found and one quarter of taxa that should have been found at the site have been lost or cannot be found.

A.2.4. Reference Condition Benchmarks

Before random sites can be assessed, a range of expected values or benchmarks must be established for each measurement (Hughes 1995; Stoddard et al. 2006). Once these benchmarks are established, data can be compared to them. For this purpose, a decision is made about what values to reference, which are usually the values actually measured in a stream reach whose condition has been determined to represent the reference condition. Reference conditions become the benchmarks against which to measure conditions found in other streams. This is a formidable challenge in making assessments of ecological condition, as it brings to the forefront several environmental, economic, and politically charged questions. Should current conditions be compared to some estimate of pre-industrial condition or to a condition from some other point in history? Is some level of anthropogenic disturbance acceptable and should the best of what’s left in today’s conditions be the benchmark to measure other streams against?

For the purposes of this study, reference condition is defined as a minimally disturbed state of the stream where human influence is low. Accurately defining and delineating this condition helps with interpreting monitoring data by creating a precise benchmark to compare those data against. If chemical, physical, and biological data are compared to the minimally disturbed site, that comparison shows how much ecological impact the data reflects.

Reference, or minimally disturbed, sites were selected in accordance with the EMAP-West project protocols and evaluated in each ecoregion to establish the quartile benchmarks and the extreme values (Lattin et al. 2004; Whittier et al. 2007). Reference sites were pooled by ecoregion and without regard to state boundaries to alleviate the difficulty of finding enough sites within each ecoregion to be able to adequately describe reference condition for that ecoregion. Typically, the 25th percentile (lower quartile) was the break-point between Good and Fair sites and the 5th percentile was the extreme value and break-point between Fair and Poor sites. For some measures, however, less is better, so the 75th percentile (upper quartile) and 95th percentiles were used. As an example, because the human disturbance value typically increases as water quality declines, more is not better. Therefore, a site scoring above the 75th percentile for human disturbance would receive a Fair designation and a site scoring above the 95th percentile would be given a Poor designation.

Physical habitat indicator benchmarks are given in Table 3. Although there are multiple options for establishing reference condition and benchmark values, the probability design of this study allows for the extrapolation of the results of any indicator to be applied to the target population as a whole. Therefore, the best way to view results is as a cumulative distribution of values over the population. Once the cumulative distribution function (cdf) is established, benchmarks can be drawn at any point along the distribution by any number of methods such as best professional judgment, societal values, or a quartile/percentile approach, to name a few. To report results in terms of condition classes (Good, Fair, Poor), benchmarks must be established, but there is additional information present in the cdf beyond simple estimates of condition classes. While there has been much debate regarding the scientific validity of setting thresholds in the manner used in this study, it is one method of breaking a continuous dataset into finite categories. There are other methods for breaking down this dataset and, depending upon the questions posed and answered, they will be equally valid. One major advantage of using cdf's is being able to apply alternative thresholds to produce different assessments based upon different decisions and judgments. For example, if decision was made to break the data into two classes, pass and fail, then a 50th percentile benchmark may be suggested, so that 49 out of 100 sites fail because they have a value less than the 50th percentile benchmark.

The chemistry benchmarks for the reference sites are shown in Table 4. Sites are grouped into the aggregate ecoregions detailed in Table 1. The benchmark values are used to divide the most disturbed stream condition from the least disturbed stream condition. Benchmark values for indicators were agreed upon between EPA and the states of Washington, Oregon, and Idaho for the EMAP-West assessment. For pH, it was determined that a value falling above the 95th or below the 5th percentiles would be considered Poor, falling between the 75th and 95th on one end or the 5th and 25th on the other would be ranked as Fair, and only those sites with pH values falling between the 25th and 75th percentiles would be considered Good. This addresses issues with streams being either too acidic or too basic, neither condition being beneficial to the biological community.

Table 3: Physical habitat benchmarks

	Mountains		Xeric	
	Quartile	**Extreme**	**Quartile**	**Extreme**
Riparian Disturbance				
Rip Dist--Sum All Types[1]	*0.33*	*0.74*	*1.00*	*1.50*
Rip Dist--Sum Agric Types[2]	*0.00*	*0.12*	*0.67*	*1.50*
Riparian Vegation				
Three Riparian Layers Present	*0.84*	*0.23*	*0.55*	*0.00*
Mean Mid-channel Canopy Density (%)	*52.41*	*12.83*	*47.33*	*1.47*
Habitat Complexity				
Fish Cover	*0.20*	*0.05*	*0.20*	*0.08*
LWD Vol in/abv Bf chan[3] (#/100m-all sizes)	*1.38*	*0.00*	*0.37*	*0.00*
Fast Wtr Hab[4] (% riffle and faster)	*39.00*	*22.77*	*54.67*	*20.00*
Slow Wtr Hab[5] (% glide and pool)	*61.00*	*77.23*	*45.33*	*80.00*
Mean Residual Depth[6] (m^2/100m)	*3.60*	*1.81*	*6.74*	*2.57*
Streambed Stability				
Relative Bed Stability	*-0.85*	*-1.74*	*-2.02*	*-2.93*
Mean Embeddedness	*52.13*	*62.64*	*62.78*	*86.67*
Substrate Fines (Silt/Clay)	*4.29*	*13.33*	*22.86*	*62.86*
Substrate Sand and Fines	*14.29*	*28.57*	*29.52*	*71.43*

Rip Dist--Sum All Type – Riparian Disturbance, sum of all types
Rip Dist--Sum Agric Types – Riparian Disturbance, sum of agricultural types
LWD Vol in/abv Bf chan – Large Woody Debris in/above bankfull channel
Fast Wtr Hab – Fast water habitat
Slow Wtr Hab – Slow water habitat

Table 4: Chemistry benchmarks

	Mountains		Xeric	
	Quartile	**Extreme**	**Quartile**	**Extreme**
H	6.2	6.9	7.1	7.3
Sulfates (mg/L)	1.3	4.1	2.1	4.1
Chloride (mg/L)	0.3	0.5	1.5	3.8
Total Suspended Solids (TSS)	1.5	10.6	6.6	22.9
Total Nitrogen(mg/L)	0.11	0.40	0.26	0.40
Total Phosphorus (mg/L)	0.01	0.02	0.04	0.07
Conductivity (μS/cm^2)	63	116	104	136
Dissolved Oxygen (State Standard, mg/L)	6	6	6	6

A.2.5. Aquatic Indicators of Stress

Certain physical and chemical characteristics of the stream are indicators of stress. The physical characteristics of interest in EMAP are related to habitat and are often referred to as physical habitat characteristics. Those used as parameters in this study are described below. The chemical parameters included in this study are described after the physical habitat parameters below.

A.2.5.1. Physical Habitat

Physical habitat refers to the portion of the stream environment that provides living space, food, and shelter for the organisms living in the stream (Kaufmann, P.R. et al. 1999). The physical habitat parameters measured and analyzed in this study include riparian disturbance, riparian vegetation, habitat complexity or fish cover, and streambed stability. "Riparian" refers to the immediate surroundings of the stream, where vegetation, when present, can filter nutrients, sediment, and chemical pollutants out of runoff before it reaches the stream.

Riparian disturbance

Human influence alters riparian vegetation by changing its composition, often replacing native plants with non-native invasive species, and by reducing coverage or even eliminating riparian vegetation completely. Measures of riparian disturbance evaluated for this report include: *percentage of riparian disturbance due to agriculture* (percentage agriculture) and *percentage of riparian disturbance due to all types of human influence* (percentage). Visual estimates of human influence are collected by the EMAP field crews at 11 cross section transects and include activity on the bank, within 10 meters of the bank or more than 10 meters from the bank but within site. The estimates are then combined and scored from 0 (no observed disturbance) to 6 (four types of disturbance observed within the stream throughout the reach or a total of six types of disturbance observed on the banks throughout the reach). Therefore the metric is weighted according to the proximity of the disturbance and is considered a proximity weighted pressure.

Riparian vegetation

A complex, multi-layered vegetation corridor along streams and rivers is indicative of a healthy stream network that is buffered against sources of stress in the watershed. Healthy riparian areas can help reduce nutrient and sediment runoff from the surrounding landscape, prevent bank erosion, provide shade to reduce water temperature and provide leaf litter and large woody debris that serve as food and habitat for stream organisms. Larger trees in the riparian corridor indicate a mature community. The presence of smaller woody vegetation typically indicates that riparian vegetation is reproducing. This suggests the potential for future sustainability of the riparian corridor. Canopy cover is also important in moderating stream temperatures through shading. For this study, the measures of riparian vegetation complexity include the sum of woody cover provided by three layers of riparian vegetation (all riparian vegetation) and the shade provided by the riparian in the mid stream channel by the riparian vegetation. Riparian vegetation structure is recorded at each transect through visual estimates of the amount of cover in the tallest canopy layer, the mid-height understory layer, and the lowest ground cover layer. Potential disturbance to these layers is indicated by noting cover classes and how sparse or heavy the vegetation is.

Habitat complexity

Habitat complexity measures the overall complexity of the channel that is beneficial to aquatic organisms. Human influence can alter the channel by eliminating complexity and fish cover. Measures of habitat complexity in this study are: *percent of instream fish cover, woody debris present in the channel, percent of substrate that is fines, percent of substrate that is sand and fines,* and *mean residual depth.* The crew measures substrate size and embeddedness using a modified Wolman pebble count of 105 particles systematically spaced along 21 equally spaced transects. The size and number of pieces of large woody debris in the bankfull channel were tallied along the entire length of the sample reach. Channel incision and the dimensions of the wetted and bankfull stream channel were measured at 11 equally spaced transects. Fish cover was visually assessed on 10 meter long instream plots.

Streambed stability

Streambed stability is the describing of the stream's substrate and its subsequent effects on the biological community. Substrate provides habitat for benthic macroinvertebrates, spawning fish, and juvenile fish. When substrate has more fine sediment, this changes the habitat by filling in the spaces between larger particles. One measure of streambed stability reported here is the *relative bed stability index* derived by Kaumann et al. (Kaufmann, P. R. et al. in press). This index uses routine survey data and sediment transport theory to create an index that evaluates the influence of human disturbance and stream characteristics on the stream substrate and the ability of the stream to move substrate. Relative bed stability measures the median diameter of substrate and compares it with the critical diameter capable of being moved during the heaviest streamflows. This index is derived from measurements of substrate size and channel dimensions measured at the 11 cross sectional transects. Decrease in the substrate size and an increase in fine sediment indicate more upland erosion or destabilized streambanks, and a greater sediment supply and subsequent loss of aquatic habitat (Klemm et al. 2003). Two other measures of streambed stability reported here are the percent of substrate that is fines (silt or clay), and the percent of substrate that is sand and fines. These two measures evaluate the amount and rate of sedimentation within a stream.

A.2.5.2. Chemical/Physical

Water quality chemical and physical parameters that were measured in this study include: pH, sulfate, chloride, total suspended solids, total nitrogen, total phosphorus, conductivity and dissolved oxygen. Conductivity quantifies the concentration of dissolved ions in the water and may be used as a surrogate measure of total dissolved solids or chemical pollutants. Nitrogen and phosphorus both encourage plant and algae growth. But when these nutrient levels are too high, plant growth may occur to the point that plants and algae rob the water of oxygen needed to support other aquatic life. Therefore, in excess, nitrogen and phosphorus become pollutants of concern.

A.3. Results

Overall condition of the waters in Idaho is good as determined by the biological communities measured. Figure 4 and Figure 5 detail the condition classes of all streams for macroinvertebrate integrity and macroinvertebrate taxa loss. In Idaho, 35% of streams are rated Good for macroinvertebrate integrity and 60% are rated Good for minimal taxa loss. The ratings are Good, Fair and Poor are described more completely in the section on setting expectation/reference condition. Briefly, a condition class rating of Good is given to those sites that are better than the 25th percentile of reference condition; Fair are those sites between the 5th and 25th percentile of reference and Poor are those worse than the 5th percentile. In the case of chemical constituents this condition class rating system translates to concentrations that are better (typically lower concentrations) than the upper 25th percentile concentration, between the upper 5th and 25th percentile concentration and worse than the upper 5th percentile concentration of reference condition. Therefore, a condition class rating of Poor for nitrogen typically indicates that nitrogen concentrations are higher than found in 95 percent of reference sites evaluated.

Figure 4: Macroinvertebrate community integrity as measured by the macroinvertebrate multi-metric index (MMI).

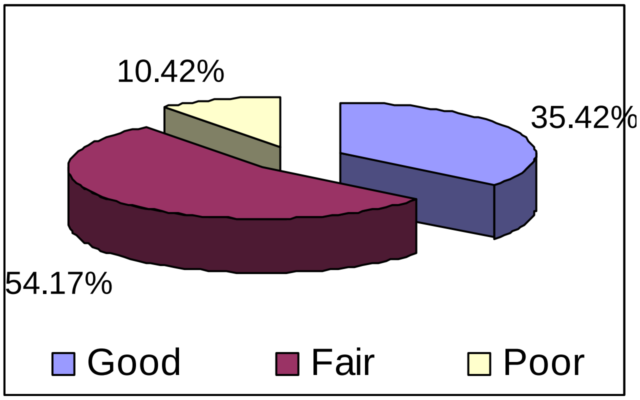
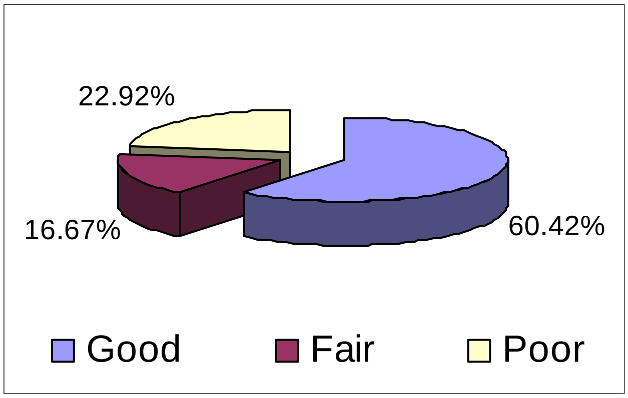


Figure 5: Macroinvertebrate taxa loss as measured by the observed to expected taxa ratio (O/E).



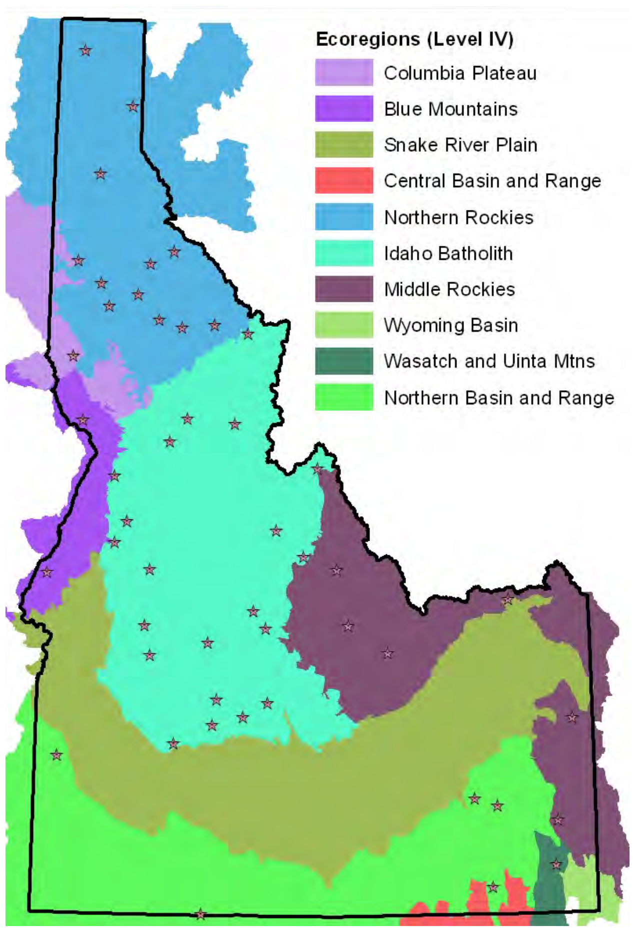
Results for all the measured parameters are shown in Appendix A. These results suggest that, overall, roughly 44% of the stream length in Idaho is in Good condition for physical habitat and 43% has a Good rating for chemistry, while approximately 15% is in Poor condition for physical habitat and 22 % has a Poor rating for chemistry, although results vary according to the parameter being assessed. One major difference indicated is between the two major aggregate ecoregions. In the mountainous regions of Idaho, 52% of physical habitat is rated in Good condition and 44 % with a Good rating in chemistry, while the xeric regions show only 37% with Good physical habitat and 29% with a Good rating in chemistry. One explanation for this variation is that the mountainous regions of Idaho tend to have far less urban and agricultural development and therefore are less likely to be influenced by human impacts. The xeric regions of Idaho are also subject to dewatering, which can have a massive impact on the chemical, physical, and biological parameters. Only about 17% of the mountainous regions are rated Poor for physical parameters and 25% with a Poor rating in chemistry while 34% of the xeric regions are rated Poor for physical habitat and 65% with a Poor rating in chemistry.

A.3.1. Extent

Data analysis for the stream sites monitored through EMAP protocols can help describe the ecological condition of Idaho streams. Since the EMAP probability design statistically represents the streams in Idaho, the ecological condition of sampled EMAP sites can be extrapolated to make a statement about the ecological condition of streams in the target population. The 48 random sites monitored for this assessment are shown in Figure 6.

A large number of measurements were collected from each site. Results from indicators based on all of these measurements are given in Appendix A, however, only the results for parameters that most influence the aquatic life are discussed in the narrative portion of this report. Ecological indicators are the two macroinvertebrate indices, the multi-metric index (MMI) and the observed/expected ratio (O/E). These two indices examine characteristics of the macroinvertebrate community and help describe the overall ecological condition of the stream. For the MMI, these characteristics are categorized into groups which include measures of richness, diversity, composition, functional feeding groups, habit, and tolerance to stressors. For the O/E ratio, stream sites are described according to elevation, size, gradient, latitude, and longitude and then the macroinvertebrate community present is compared to the expected community based upon reference condition.

Figure 6: Sites monitored for EMAP-West in Idaho



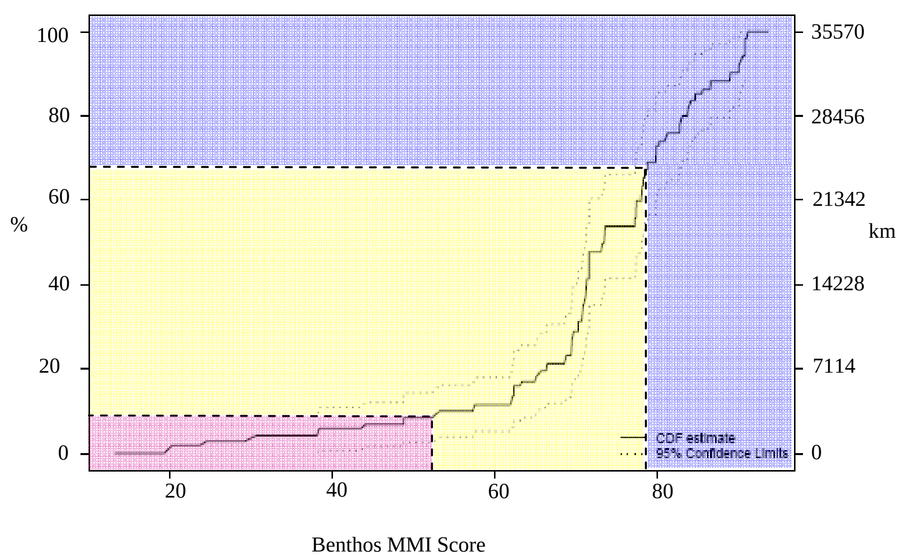
A.3.2. Ecological Condition

A.3.2.1. Macroinvertebrate Biotic Integrity

Analysis of benthic macroinvertebrate data directly addresses one goal of the Clean Water Act: to restore and maintain the *biological* integrity of our nation's waters. Groups of interacting populations, or assemblages, of benthic macroinvertebrates provide useful information in assessing the current status of streams as well as in demonstrating the long term ecological condition of streams (Cullen et al. 1999). Information about macroinvertebrate assemblages is summarized by metrics and these metrics are combined into an overall Macroinvertebrate Multi-metric Index (MMI) score. Figure 7 shows the cumulative distribution of the MMI for sites within Idaho. The cdf plot of the MMI versus percent of stream length describes the range of MMI scores across the state. As shown in the plot, approximately 10% of the stream length in Idaho has MMI values that fall below the 5th percentile of reference value MMI scores (MMI = 53), while 55% of stream length has MMI values between the 5th percentile and 25th percentile (MMI = 78) of reference. This indicates that the majority of streams in Idaho had high MMI scores and therefore streams in Idaho are likely in fair to good condition based upon the macroinvertebrate community.

As described earlier, the MMI metrics that perform best against selected habitat criteria were chosen for inclusion into the index. Different metrics were included in the MMI for the Mountain ecoregion versus the Xeric ecoregion. Data for the random sites are given in the cdf shown in Figure 7. A cdf graph shows the distribution of values for an indicator or measurement over the entire dataset (Diaz-Ramos et al. 1996). The dataset in this instance is all of the random sites sampled.

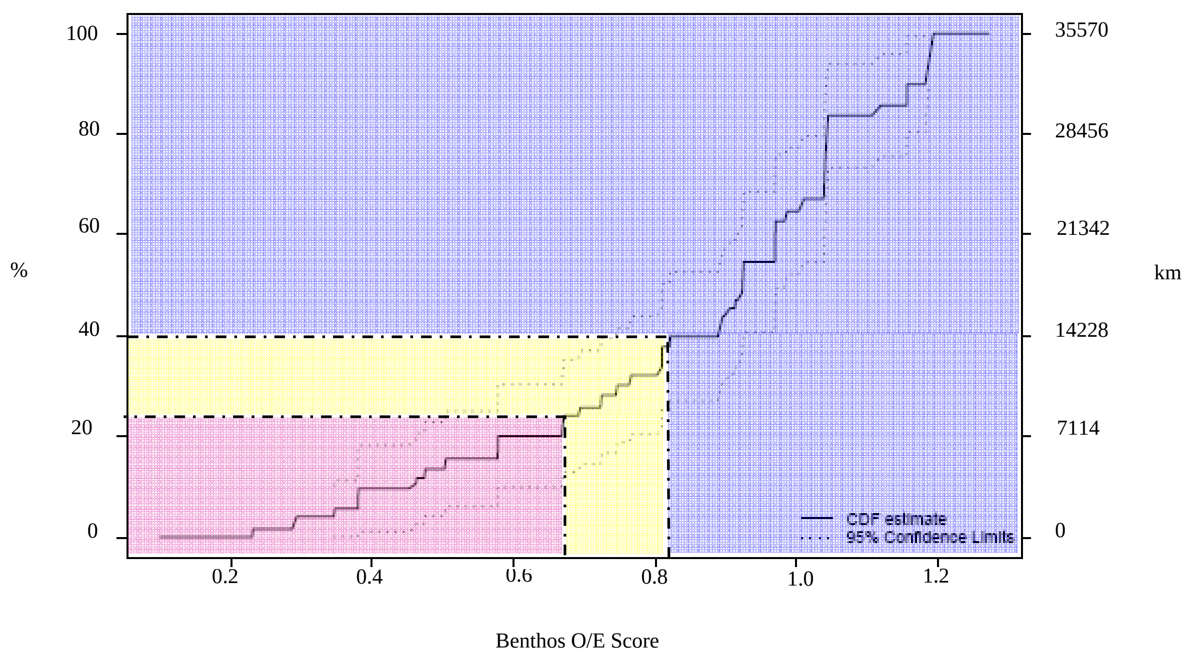
Figure 7: Cumulative distribution function of the Macroinvertebrate Multi-metric Index for all sites within Idaho plotted on the left against stream length percentage and on the right against stream length in kilometers. Shading on the distribution function corresponds to the Poor (pink), Fair (yellow) and Good (blue) condition rating categories discussed in the text.



A.3.2.2. Macroinvertebrate Observed/Expected (O/E) Ratio of Taxa

As previously detailed, the O/E Ratio models the taxonomic composition of benthic macroinvertebrates as a function of natural elements such as stream size, elevation, and gradientand is rated on a different scale than the MMI. For the O/E Ratio, 75% of reference sites had at least 82% (O/E = 0.82) of the expected taxa present, while 95% of reference sites had more than 67% of expected taxa. These values represent the 25th and 5th percentile values used as thresholds for the good-fair and fair-poor condition ratings. Figure 8 shows the cdf of the O/E ratio for sites within Idaho. The cdf plot of the O/E ratio versus percent of stream length describes the range of O/E scores across the state. As shown in the plot, 23% of the stream length in Idaho has O/E values that fall below the 5th percentile of reference value O/E scores (O/E = 0.67), while 17% of stream length has O/E values that fall between the 5th percentile and 25th percentile (O/E = 0.82) of reference. This indicates that the majority of streams in Idaho had high O/E scores and therefore streams in Idaho are likely in Good condition based upon the macroinvertebrate community.

Figure 8: Cumulative distribution function of the Macroinvertebrate O/E Score for all sites within Idaho plotted on the left against stream length percentage and on the right against stream length in kilometers. Shading on the distribution function corresponds to the Poor (pink), Fair (yellow) and Good (blue) condition rating categories discussed in the text.



A.3.3. Aquatic Indicators of Stress

A.3.3.1. Physical Habitat

Reference sites were compiled across ecoregions, regardless of state boundaries, and evaluated to determine the 25th and 5th percentile values used to determine the condition ratings. For the Mountains aggregate ecoregion there were 16 reference sites used to determine these values, while for the Xeric aggregate ecoregion there were between 10 and 13, depending upon the metric being evaluated. The benchmarks established by these reference percentiles are shown in Table 3. Pie charts showing the percentages of stream miles in each condition class for all physical habitat stressors can be found in Appendix A, while cumulative distribution functions for those parameters can be found in Appendix B.

Riparian Disturbance

Riparian Disturbance – Riparian disturbance metrics evaluated for this category are the percentage of riparian disturbance due to agriculture and percentage of riparian disturbance due to all types of human influences. According to the proximity weighted measure of all human influence, 45% of the State's stream length is minimally disturbed and is rated as good, while 39% shows significant disturbance and is rated as Poor. Broken down by ecoregion, 47% of the Mountains region stream miles are in Good condition for all human influence, while 31% in the Xeric region are in the Poor condition rating category (Appendix A: Proximity Weighted Riparian Disturbance (All Human Pressures)). Based upon ecoregion, 47% of the stream miles in the mountains are in Good condition, while in the Xeric region there are 31% in Good condition. Riparian disturbance due to agriculture shows a similar trend with the Mountain ecoregion showing fewer disturbances from agriculture. The Mountains region has 72% rated as being in the Good condition rating while the Xeric region has only 40% in Good condition (Appendix A: Proximity Weighted Riparian Disturbance (Agricultural Pressures).

Statewide, 60% of the stream length had minimally disturbed riparian areas. When compared to the measure of human influence, the fact that there is a higher percentage of streams with minimally disturbed riparian areas than streams with minimal human influence suggests that there has been effective management of human activities that preserves the riparian area in areas with human influence. When these results are broken down by ecoregion, however, 63% of the stream length in the Mountain region is minimally disturbed while 32% of the stream length in the Xeric region is minimally disturbed. Greater urban and agriculture land use (Figure 9) in the significantly drier Xeric region (Figure 1) may lead to this greater disturbance along the riparian area of xeric streams.

Riparian Vegetation

Another physical habitat indicator is riparian vegetation. One measure of riparian vegetation is the amount of it that is present in the canopy, mid level, and ground cover layers. These woody vegetation layers are defined as follows:

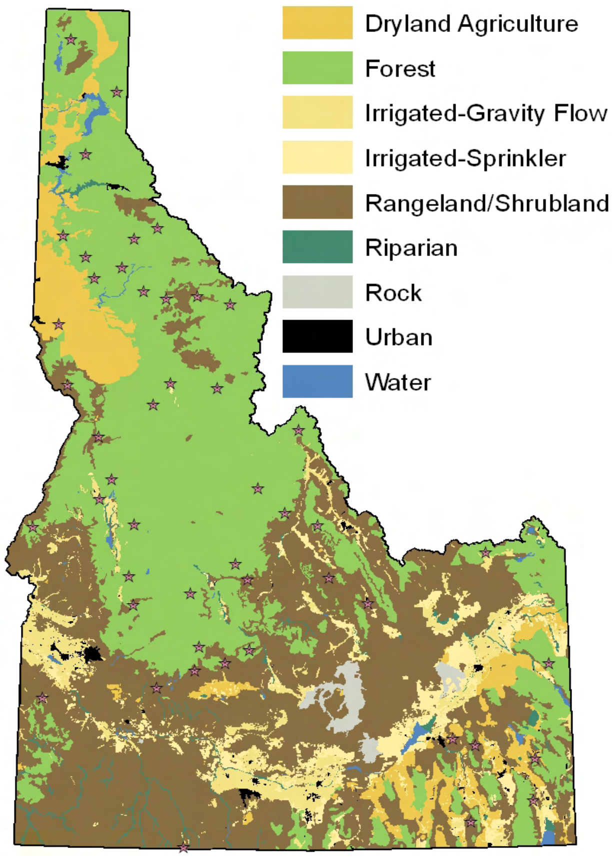
Canopy layer = > 5 meters in height,

Mid level layer = 0.5 to 5 meters in height,

Ground cover layer = < 0.5 meters in height.

Visual estimates were made of the amount of riparian vegetation in each layer (Peck et al. 2005b). A maximum value of 3 was given to a riparian area where there was 100% cover in all three layers. Although 100% cover in all three layers is unlikely (especially in Xeric streams), these values are compared to the reference condition which compensates for this.

Figure 9: Land use patterns in Idaho



In-stream Habitat

For each of 11 transects at each EMAP monitoring site, the EMAP crews visually estimated cover class category. The fish cover types were filamentous algae, aquatic macrophytes (rooted plants), large debris, brush, live trees or roots in the channel, overhanging vegetation, undercut banks, boulders, and artificial structures. For each of these cover types that could conceal fish, field crews estimated how heavy or sparse the cover was. These estimates were then averaged across the 11 transects into a fish cover metric value. Overall, 49% of the stream length in Idaho is in Good condition with regard to in-stream fish cover. This breaks down to 53% in Mountain streams and 9% in Xeric streams. Within the Xeric region 41% of the stream length fish cover is in Poor condition when compared to the reference condition.

Streambed Stability

Within Idaho, 34% of the stream length is classified as being in Good condition with regard to the relative bed stability index, 50% is Good for the percent of substrate that is fines (silt or clay), and 44% is Good for the percent of substrate that is sand and fines. When averaged and weighted, this suggests that 43% of the streams in Idaho have not been significantly impacted by sedimentation. The percentage of streams in Fair condition for the same indices are 58% for relative bed stability, 30% for percent fines and 40% for percent sand and fines. The overall percentage of streams with a Fair condition rating when looking at sedimentation is also approximately 43%. A condition rating of Fair is on the border between Good and Poor and so that proportion of stream length may or may not have significant sedimentation issues and should be evaluated on a more site-specific basis. The remaining 14% leads to the conclusion that approximately 14% of the stream length in Idaho has been significantly impacted by sediment.

Other physical habitat stressors

Other physical habitat stressors that were evaluated include mean mid-channel canopy density, large woody debris, mean residual pool depth, percent slow water habitat (glides/pools), percent fast water habitat (riffles/runs), and embeddedness. Results for these stressors are found in Appendices A and B.

Condition based on all physical habitat stressors

Based upon all physical habitat stressors, 50% of the stream length in Idaho is in Good condition and only 14% is in Poor condition. In the Mountain region 52% of streams are in Good physical condition and 44% are rated Good for chemical parameters. In the Xeric region, those portions change to 37% and 29%, respectively.

Table 5: Other physical habitat parameters and the percentage of stream kilometers in each condition class.

	GOOD	FAIR	POOR
Mean Mid-channel Canopy Density (%)	69%	26%	5%
Large Woody Debris in/above Bankfull channel (#/100m-all sizes)	55%	45%	0%
Mean Embeddedness	42%	35%	23%
Mean Residual Depth (m2/100m)	37%	60%	3%
Fast Water Habitat (% Riffle & Faster)	56%	14%	31%
Slow Water Habitat (% Glide & Pool)	56%	15%	29%

A.3.3.2. Chemistry

Water chemistry is a traditional measure of aquatic condition. However, it only provides data at the time it was collected, which do not necessarily represent the aquatic condition for longer periods of time before the sample was taken. For variable water chemistry, the peak conditions are not necessarily represented in the dataset. Although 20 chemical parameters were analyzed from the EMAP samples, only the four parameters with the highest impact on Idaho streams are discussed here (sulfates, total phosphorus, total nitrogen, and conductivity). As shown in Table 6, the parameter with the largest proportion of stream miles in poor condition is sulfate concentration Although it was initially suspected that total nitrogen or total phosphorus would be the greatest chemical stressor, the results show that total nitrogen is the cause of only 5.5% of stream length being classified as Poor. Total phosphorus is significantly higher with 37%. Sulfates are only slightly higher than total phosphorus with 38% of stream miles being classified in Poor condition for sulfates.

In the Mountain region 32% of stream length was rated Poor for sulfates, none for total nitrogen, 34% for total phosphorus, and 20% for conductivity. In the Xeric region, however, there is a

Table 6: Proportion of stream lengths statewide in various condition categories for select chemical parameters.

Chemical Parameter	Proportion of Stream Length		
	Good	**Fair**	**Poor**
Sulfates	29.60	31.79	38.60
Total_Nitrogen	48.48	45.98	5.54
Total_Phosphorus	44.45	18.68	36.87
Conductivity	52.26	20.27	27.48

significant change in the proportion of streams in Poor condition: 91% are rated as Poor for sulfates, 52% for total nitrogen, 64% for total phosphorus, and 91% for conductivity. This highlights a significant difference found between the Mountain and Xeric and regions. Overall, roughly half the streams throughout the state are in Good condition based on chemistry, however, a significantly higher proportion of streams in Poor condition for chemistry are in the Xeric region.

Table 7: Proportion of stream length in Poor condition statewide and in each of the ecoregions.

Parameter	Statewide	MT	XE
Total Suspended Solids	15%	13%	30%
Sulfates	39%	32%	91%
Chlorine	30%	25%	74%
Total_Phosphorus	37%	34%	64%
Total_Nitrogen	6%	0%	52%
Conductivity	27%	20%	91%

A.4. Ranking of Stressors

There are three general assessment goals of EMAP-West: 1) to show the proportion of streams in acceptable biological condition, 2) to identify the relative importance of potential stressors, and 3) to show which stressors the disturbed streams are most closely associated with. The previous sections have detailed the proportion of streams in Good, Fair and Poor condition. To achieve the other two goals, stressors were ranked according to the extent they were found throughout streams in Idaho. These stressors were then assessed to determine the proportion of streams that were found to be in most disturbed condition due to each potential stressor and ranked accordingly. Once the extent of each stressor was determined, the risk it poses was determined. Relative risk is a measure of the likelihood or probability a stream will have a Poor biological condition rating if it is rated Poor for a given stressor versus the likelihood of the stream being in Poor biological condition if it is rated as Good for that stressor.

A.4.1. Extent

Extent shows how widespread the Poor condition rating is throughout Idaho for stressors identified by the habitat indicators. Relative extent is the sum of the sites in Poor condition divided by the total number of sites multiplied by 100. Therefore, relative extent is a percentage of sites estimated to be in Poor condition for each variable. Figure 10 shows the relative extent of all physical and chemical stressors assessed statewide.

The majority of streams are in either good or fair condition based on physical stressors. The indicator showing the largest relative extent of poor condition in Idaho is riparian disturbance, followed by embeddedness and substrate fines. This indicates that the physical habitat parameters most associated with poor condition are due to changes in the riparian area and the addition of sediment to the stream channel. It is interesting to note that sites with a riparian disturbance due to human disturbance rating of Poor show the highest extent throughout the State.

As with the physical stressors, the majority of streams are in either Good or Fair condition for chemical stressors. The three chemical stressors with the greatest extent of streams in Poor condition are sulfates, total phosphorus, and chloride. The extents of these are 39%, 38%, and 29%, respectively. Total nitrogen and pH show the lowest extent of streams in Poor condition, 6% and 4%, respectively.

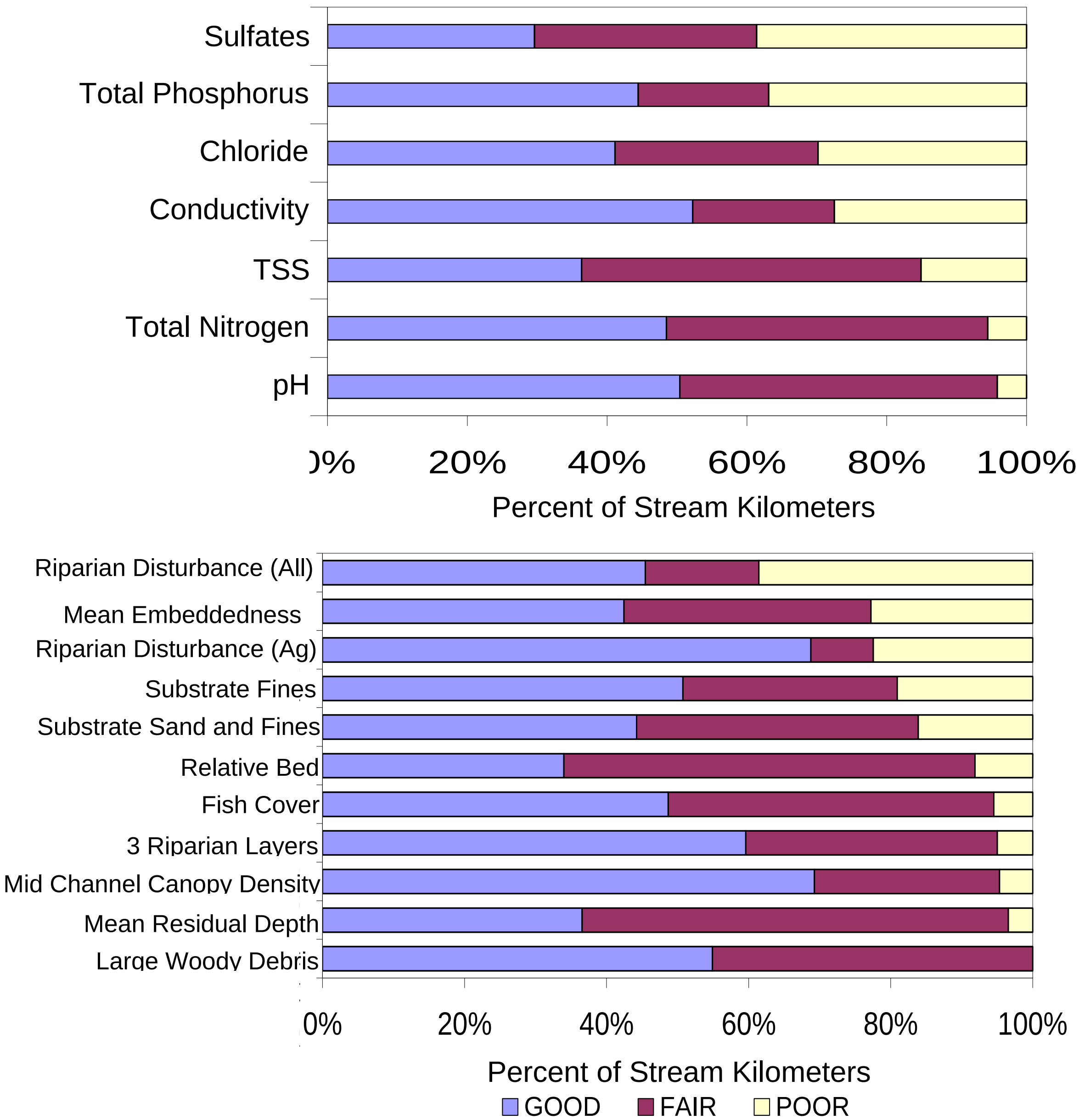
A.4.2. Relative Risk

Relative risk is a way of looking at a stream's condition with regard to more than one variable at a time. It measures the probability that Poor biological condition and Poor stressor conditions occur in the same stream at the same time (Van Sickle et al. 2005). Figure 10 shows the relative risk of each habitat and chemical indicator with respect to both the Multi-metric Macroinvertebrate Index (MMI) and the Observed/Expected Ratio of Taxa Loss (O/E Ratio) for the Mountain sites and for the Xeric sites.

When relative risk is 1.0, the stressor is said to have no effect on the biological indicator. For example, at a risk of 1.0, it is equally likely to have a Poor MMI score in streams with Good levels of nitrogen as in streams with poor levels of nitrogen. Relative risk greater than 1.0 indicates a risk. Figure 10 is a graphical representation of relative risk for each of the stressors evaluated in this report. Bothe the MMI and O/E ratio are plotted.

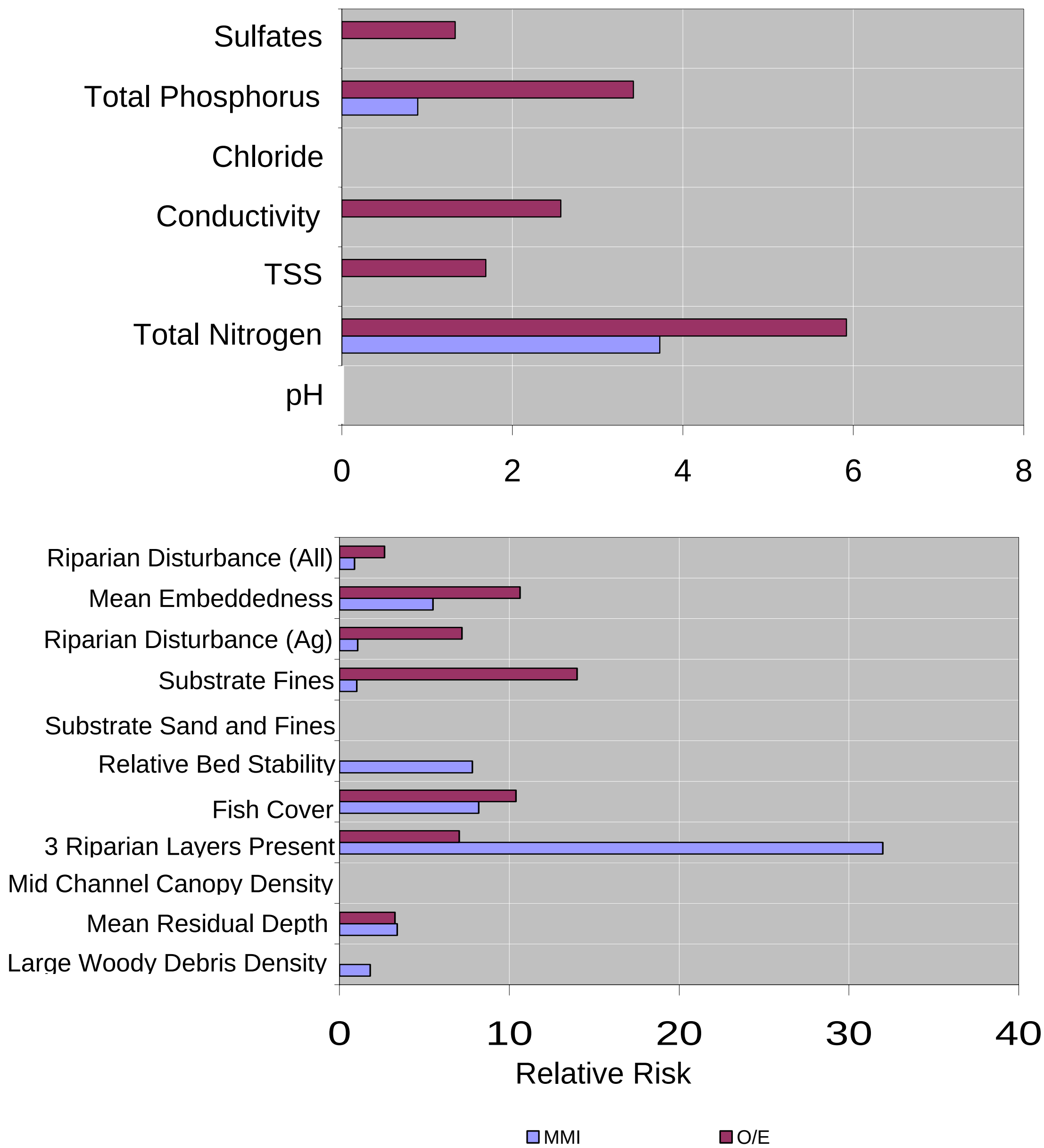
For macroinvertebrate community integrity (MMI), the highest risks are associated with riparian vegetation, relative streambed stability, and fish cover (physical habitat). For taxa loss, the O/E shows the highest risks to be associated with substrate fines, mean channel embeddedness, and fish cover. There is a significant risk associated with removal of the canopy for macroinvertebrate community integrity. There is a 32-fold increase in the chance of getting a Poor biological condition rating if the metric for the three riparian layers is Poor. Other risks are 8.2 for fish cover and 7.8 for relative bed stability

Figure 10: Relative Extent of Stream Kilometers in Good, Fair and Poor condition classes



For chemical stressors, the top risks to macroinvertebrate community integrity are total nitrogen and total phosphorus, while the top three risks to loss of taxa are from total nitrogen, total phosphorus, and conductivity. There is significant risk to the macroinvertebrate community then from nitrogen and phosphorus as these two pose a risk to both community integrity and taxa loss. The next section describes how information regarding extent can be combined with relative risk to help focus efforts to restore and protect streams

Figure 11: Relative risk for both macroinvertebrate integrity (MMI) and macroinvertebrate taxa loss (O/E)

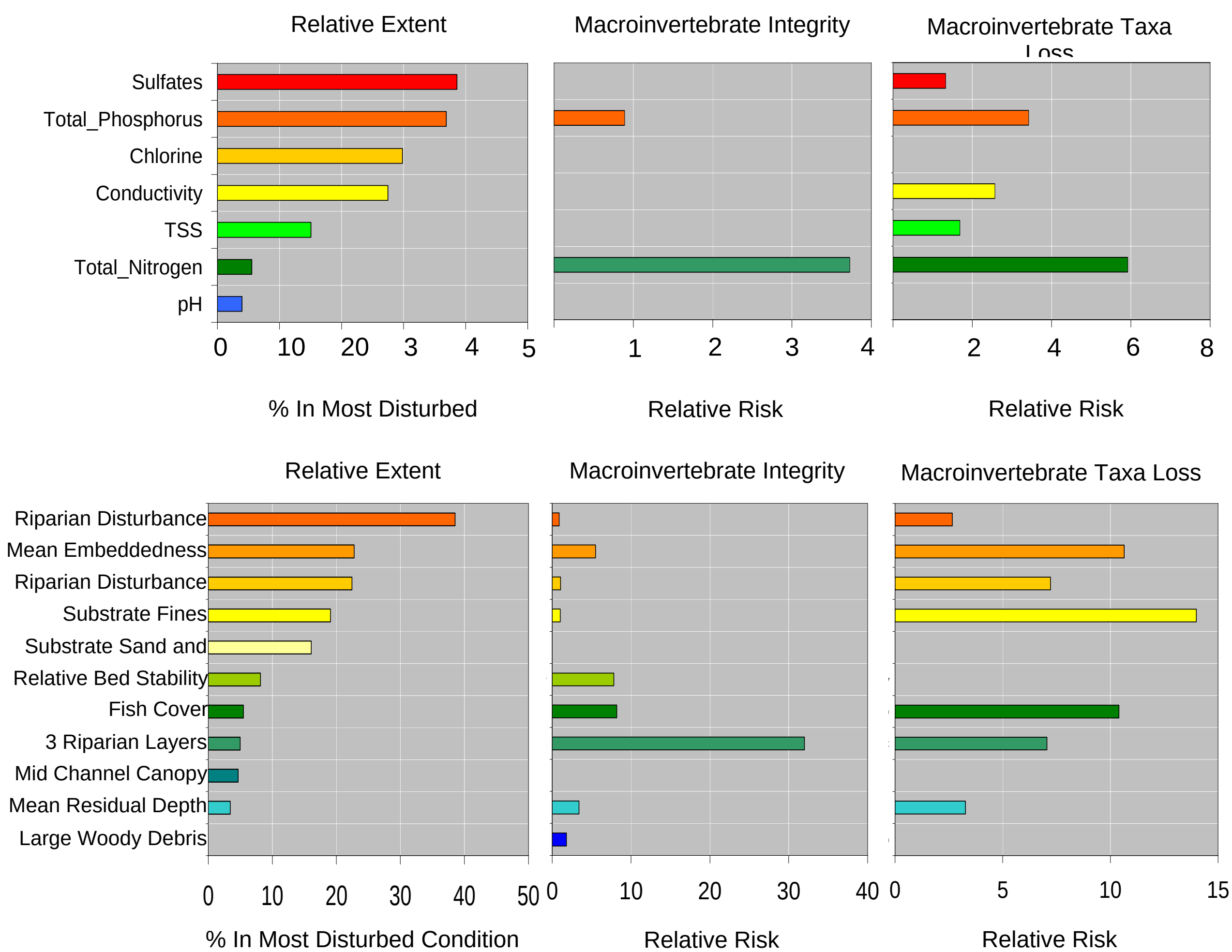


A.4.3. Combining Extent and Relative Risk

Once relative risk (RR) and extent of the stressors have been determined, the best way to assess the results is to combine the two (Figure 12). Stressors that show the highest overall risk to biological communities are posed by those stressors that are both widespread and have a potentially significant effect. Analysis of the data shows that total phosphorus is a chemical stressor of significant concern in Idaho due to its relatively great extent (37% of streams are rated Poor due to phosphorus) and its high risk of affecting the biological community (RR of 3.4 for taxa loss). Total nitrogen is another concern due to its high relative risk for both macroinvertebrate community integrity and taxa loss, however, there is such a small proportion of streams that are rated Poor due to total nitrogen concentration that it is likely not the first suspect in stream pollution.

It would appear that there are significantly more physical habitat stressors that are of interest. The risks associated with substrate fines, embeddedness, and riparian disturbance from agriculture are highest for taxa loss, while canopy cover has a significantly higher risk for macroinvertebrate community integrity. In evaluating physical habitat stressors, fish cover, riparian vegetation, and embeddedness are the stressors of highest concern when both the extent and relative risk to the biological community are evaluated. Degradation of fish cover affects only 5% of the stream length, but it has relative risks of 8.2 and 10.4 for integrity and taxa loss, respectively. Riparian disturbance has an extent of 39% with relative risks of 1.0 and 2.6 to integrity and taxa loss, respectively. Remembering that an RR of 1.0 indicates that there is no increase in risk, riparian disturbance, although widespread, does not present as much of a concern as would embeddedness, the next most widespread stressor. Embeddedness has an extent of 23% with relative risk values of 5.5 and 10.6 for the MMI and O/E, respectively.

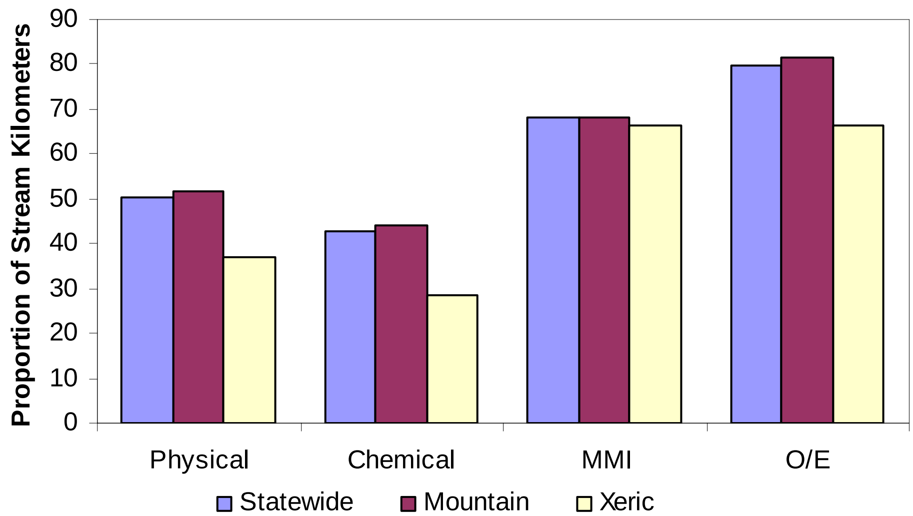
Figure 12: Relative extent and relative risk of poor condition for the 48 EMAP random sites.



A.5. Conclusions

The ecological condition of Idaho's streams and rivers is overall relatively Good, however, there are areas of concern. In the Mountain region, 52% of the stream length has Good physical habitat, 44% has Good chemistry, 68% has Good macroinvertebrate community integrity, and 81% show little or no macroinvertebrate taxa loss. There is a significant difference in the Xeric region however where only 37% is rated Good for physical habitat, 29% Good for chemistry, 66% for macroinvertebrate community integrity, and only 66% show little or no macroinvertebrate taxa loss. Overall, the waters in the State are rated as 50% in Good physical condition, 43% in Good chemical condition, 68% with Good macroinvertebrate community integrity and 80% with little or no macroinvertebrate taxa loss Figure 13

Figure 13: Proportion of stream kilometers in good condition.



When evaluating the proportion of streams statewide in Poor or most-disturbed condition, 15% of the streams are rated Poor for physical habitat, 22% Poor for chemistry, 10% Poor for macroinvertebrate community integrity, and 13% with a loss of more than 1/3 of the macroinvertebrate taxa. For the Mountain region, 17% have Poor physical habitat, 25% have Poor chemistry, 8% have Poor macroinvertebrate community integrity, and 13% have more than 1/3 macroinvertebrate taxa loss. Again, in the Xeric region, the numbers are slightly less optimistic, with 34% rated as Poor for physical habitat, 67% Poor for chemistry, 34% Poor for macroinvertebrate community integrity and 20% have more than 1/3 macroinvertebrate taxa loss.

Of the potential stressors examined, disturbance of riparian areas is most common. Nearly 40% of streams in Idaho have riparian disturbance rated in the most-disturbed category with Mountain streams having 40% in most-disturbed condition and Xeric streams having 22% in the most-disturbed condition. Sulfate and total phosphorus round out the top three widespread stressors with extents of 39% and 37%, respectively, and with concentrations outside the extreme percentile of reference condition. In the Mountain region these values are 32% for sulfates and 34% for total phosphorus. Stream proportions with Poor condition ratings for these two stressors in the Xeric region are significantly higher, with sulfates showing an extent of 91% with a Poor condition rating and 64% rated Poor for total phosphorus.

Results reported here suggest that the Mountain ecoregion is more susceptible to riparian disturbance from agriculture and other human activities while streams in the Xeric ecoregion are more likely affected by chemical stressors such as sulfates and total phosphorus.

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B. BURP vs. EMAP: Comparison of Stream Monitoring Protocols

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B.1. Introduction

As part of the EMAP pilot project, the Idaho Department of Environmental Quality (IDEQ) undertook a study in 2004 to compare data gathered using EPA EMAP protocols with IDEQ Beneficial Use Reconnaissance Program (BURP) protocols. The purpose of this study was to determine if the two protocols give statistically equivalent assessments at a 99% confidence level, based on an evaluation of the data gathered using each protocol. It was proposed that if EMAP and BURP protocols gave statistically equivalent answers, BURP protocols would be preferable to the State due to comparability with historical data collected over the last 13 years, decreased sampling time, and lower costs. Using the EMAP protocols requires 7-8 hours per team per site and approximately $5,000 per site, while BURP protocols use only 4-5 hours per team per site and $2,500 per site. The most significant difference in the protocols is the number of transects evaluated. With BURP protocols , three transects are monitored at a distance 10 channel widths apart while the EMAP protocol uses 11 transects approximately 4 channel widths apart. Although more data are gathered if more transects are used, this study examined if this increased effort was necessary and if larger quantities of data are beneficial when compared to the added effort and expense. It is hypothesized that the two methods will give statistically equivalent answers at the 99% confidence level.

B.2. Methods

During the field season of 2004, one crew trained in EMAP protocols and another crew trained in BURP protocols visited 21 sites throughout the State. Each crew visited a given site within 3 weeks of the other crew to assure there was no major temporal variation in water quality. Data from the BURP crew was entered into the statewide database while data from the EMAP crew was submitted to EPA Region 10 for analysis and storage.

For macroinvertebrates and canopy cover, raw data gathered using the two different protocols can be evaluated and directly compared. There are minor differences in the amount of data collected, e.g., 6 canopy cover readings at each transect are taken with EMAP protocols while only 4 canopy cover readings at each transect are taken with BURP protocols. However, the actual method of gathering data is the same for canopy cover, so a comparison of the data collected will evaluate if additional readings per transect and additional transects (11 for EMAP vs. 6 for BURP) give significantly different results. Macroinvertebrates are collected as outlined in the following section. One major difference in the way macroinvertebrates are collected between the two protocols is the area sampled. EMAP protocols sample a greater area of the stream bottom. Comparing the results of these two methods will evaluate if the area sampled has a significant impact on the index value.

Other data gathered using these protocols cannot be directly compared, so overall site assessments were compared. In order to assess a site with EMAP data, a Condition Index (CI) was developed based upon metrics that relate to those metrics used in Stream Habitat Index (SHI) developed for Idaho DEQ and described in further detail in the Idaho Small Stream Ecological Framework (Grafe, C.S. 2002b). The CI is described in Section B.2.2. Assessments based upon the thresholds established for the statewide EMAP assessment were compared to assessments based upon the BURP data as outlined in the Water Body Assessment Guidance (Grafe et al. 2002).

Due to time, cost, and permitting restrictions, aquatic vertebrates were only sampled by the BURP crew and are not part of this study.

B.2.1. Canopy Cover

Canopy cover measurements were taken using a densiometer. For the EMAP sites, six readings were taken at each of 11 transects. For the BURP sites, four readings were taken at each of three transects and again 10 meters above each transect for a total of 6 transects. To normalize the readings at each transect, densiometer readings were summed across the transect and then multiplied by a constant. This constant was used to create standardized values on a 0 - 100 % scale. For the EMAP readings, the constant was 100/(17*6) which normalizes the summed readings to 100%. For the BURP readings, the constant was 100/(17*4). The standardized transect readings were then averaged for all transects to give an overall percentage of canopy cover for the reach. These overall values were plotted and analyzed for correlation.

An F-test was used to compare variances of the canopy cover measurements at the 99% confidence level. A correlation coefficient was calculated and compared to critical values at the 99% confidence level to determine if there was significant correlation between the two measures of canopy cover.

B.2.2. Physical Habitat

The two methods being evaluated here have several different ways of looking at and assessing the physical environment available at each stream reach. Some of the major differences between the two protocols include collecting data at 11 transects for EMAP and 3 for BURP, a more qualitative approach to measures (rating 1-5) of human influence with the EMAP protocols, and a smaller number of particles counted in the EMAP protocol than BURP. Table 8 details in greater depth the differences between the EMAP and BURP protocols by looking at the metrics used in calculating the Stream Habitat Index. Because there are no established indices for habitat using the EMAP-West data, a Condition Index (CI) was established using those metrics available for the EMAP data that were the most closely associated with variables already established in the Stream Habitat Index (SHI). This Condition Index is detailed further in the results following this section.

Table 8: Comparison of BURP and EMAP stream physical habitat monitoring protocols.

SHI Habitat Measure	EMAP protocol	BURP protocol
Disruptive pressures (Riparian Vegetation)	Nothing equivalent in EMAP, but can compare to "human influence" visual riparian estimate, consisting of eleven categories that are either: - not present - more than 10 meters from the bank - within 10 meters of the bank, or - on the bank.	Human disturbance causing disruption of streambank vegetation. 0 – 2 = < 30% of potential vegetation 3 – 5 = 30 - 60% of potential vegetation 6 – 8 = 60 - 90% of potential vegetation 9 – 10 = Most of potential vegetation remains.
% Bank vegetation cover (Three Riparian Layers Present)	Percentage of canopy layer, understory, and ground cover that is providing cover for the streambank. Reported as percentage.	0 – 2 = < 50% of the bank covered by vegetation 3 – 5 = 50 - 79% 6 – 8 = 70 - 80% 9 – 10 = > 90%
% Canopy cover (Mean Mid-channel Canopy Density)	Densiometer readings of 0-17 for six positions at each of 11 transects.	Densiometer readings of 0-17 for four positions at each of six locations.
Instream cover (Fish Cover)	0 = absent 1 = sparse: < 10% 2 = moderate: 10 - 40% 3 = heavy: 40 - 75% 4 = very heavy: > 75% Types = filamentous algae, macrophytes, large woody debris, brush, roots, overhanging vegetation, undercut banks, boulders, and artificial structures.	0 – 5 = < 10% 6 – 10 = 10 - 30% 11 – 15 = 30 - 50% 16 - 20 = > 50% Types = cobble, gravel, large woody debris, undercut banks, or other fish cover.
Large woody debris --number of pieces (LWD Vol)	Tally all pieces that are at least partially within the bankfull channel that are at least 10 centimeters in diameter and 1.5 meters in length.	All pieces greater than ten centimeters in diameter and one meter in length within the bankfull channel.

SHI Habitat Measure	EMAP protocol	BURP protocol
Embedded-ness	For particles larger than sand, the surface is examined for stains, algae, and markings to estimate the percentage of the particle that was embedded in the substrate. Ranked by percentage.	For particles larger than sand, the surface is examined for stains, algae, and markings to estimate the percentage of the particle that was embedded in the substrate. Ranked as 0 - 20.
Wolman size classes (number) (Relative Bed Stability)	Size classes recorded five times at each of eleven transects for a total of 55 counts.	Size classes recorded at three riffle transects at equal intervals until a minimum of 150 particles have been tallied (50 per transect).
Percent fines < 2mm in wetted width	Size classes recorded five times at each of eleven transects for a total of 55 counts. Fines are 2 mm (sand) or less.	Size classes recorded at three riffle transects at equal intervals until a minimum of 150 particles have been tallied (50 per transect). Fines are 2 mm (sand) or less.
Channel shape	No channel shape measure, but EMAP does collect bank angle as 0 - 360º. Anything >90º is an undercut bank.	Dominant shape of the wetted channel: 0 – 5 = inverse trapezoidal (poor) 6 – 10 = rectangular (marginal) 11 – 15 = trapezoidal (optimal)
Zone of influence	Nothing equivalent in EMAP. Width of right and left streambank riparian areas were measured and recorded only in 2000, and were not compared to human impacts.	The width of the riparian zone as it relates to human impacts to the riparian zone width. 0 – 2 = Little or no vegetation 3 – 5 = Riparian zone at least as wide as stream 6 – 8 = Riparian zone at least 2 times the width of the stream 9 – 10 = Riparian zone at least 4 times the width of the stream

B.2.3. Macroinvertebrates

Under EMAP protocols, macroinvertebrate samples were collected using a D-frame kick net (500-mm mesh) and sampling area of 1 square foot (ft^2) at 8 targeted riffles in each reach. Overall, each site had a sample area of 8 ft^2 for the EMAP dataset and the samples were combined into a single sample at the lab. For the BURP macroinvertebrate samples, a Hess net (500-mm mesh) and sampling area of 0.92 ft^2 was used at three riffle transects giving 2.8 ft^2 total sampling area for the BURP dataset. The BURP macroinvertebrate samples were also combined into a single sample at the lab. All macroinvertebrate samples were identified to a 500 minimum individual count. Data was reported to the lowest taxonomic resolution available, generally to species.

The Stream Macroinvertebrate Index (SMI) is a tool used in assessing the biological integrity of a stream, was developed for IDEQ and is outlined in the Idaho Small Stream Ecological Assessment Framework (Grafe, C.S. 2002b). The SMI uses the following metrics to quantify stream macroinvertebrate health: total taxa richness, number of Ephemeroptera taxa, number of Plecoptera taxa, number of Trichoptera taxa, percent of individuals that are Plecoptera, Hilsenhoff Biotic Index (HBI), percent of individual in the dominant 5 taxa, number of scraper taxa, and number of clinger taxa. Raw macroinvertebrate data was downloaded from EPA's Surface Water Information Management (SWIM) system and processed using Idaho's Assessment Database Supplementary Application, which calculates the SMI. For each site, one SMI value was calculated with the EMAP data and another with the BURP data. A plot of SMI values for each site was created and evaluated for linearity. Each metric within the SMI was also evaluated separately for all sites to determine what differences were inherent in the index.

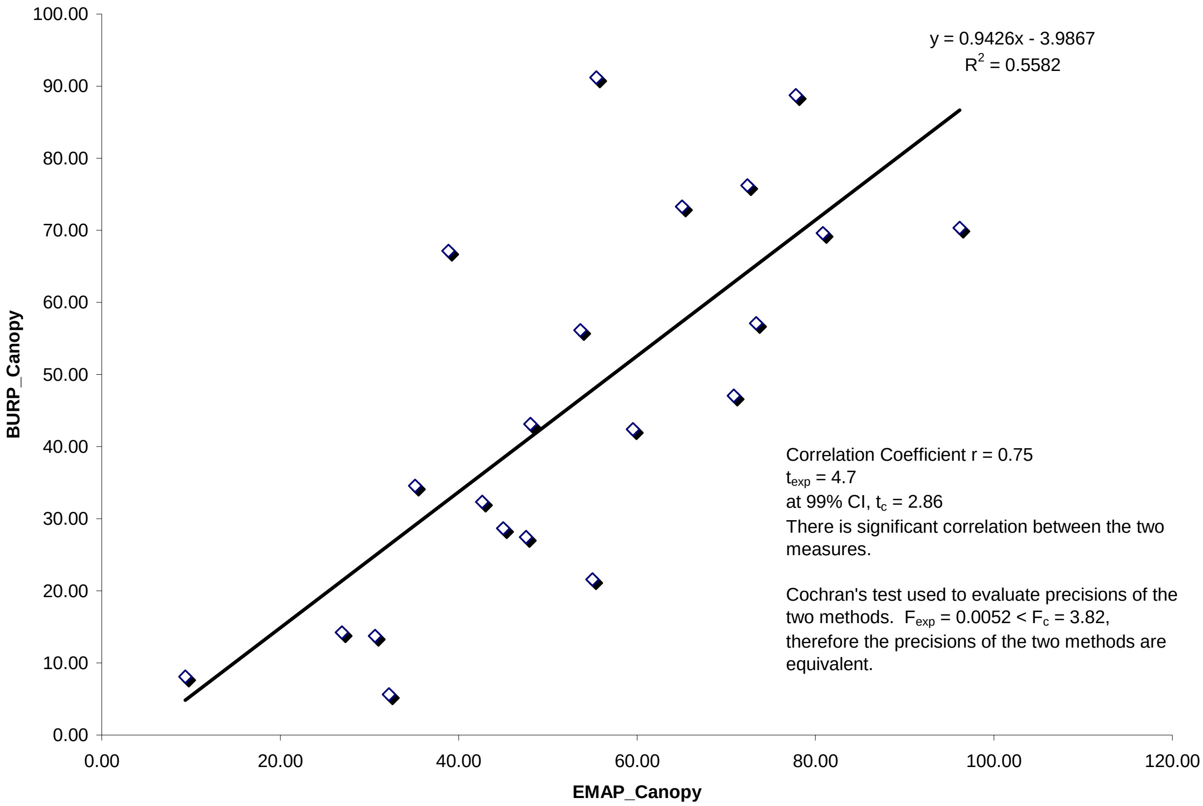
Macroinvertebrate data from the EMAP dataset and the BURP dataset were compared using a paired Student's t-test. A correlation coefficient was determined for the SMI values and compared to critical values to determine if there was significant correlation between the two datasets at the 99% confidence level.

B.3. Results

B.3.1. Canopy Cover

Evaluation of the measures of canopy cover shows significant correlation between the two protocols. Cochran's test was used to evaluate the precision of the two methods, with the experimental F-value at 0.0052. This is lower than the critical F-value of 3.82, indicating that the precision of the two methods is statistically equivalent.

Figure 14: Correlation of Canopy Cover measurements between BURP and EMAP protocols.



B.3.2. Physical Habitat

The ten metrics evaluated to create the Condition Index (CI) from the EMAP data are:

1. Riparian Disturbance--Sum All Types (Proximity Weighted Pressure),
2. Riparian Disturbance--Sum Agricultural Types (Proximity Weighted Pressure),
3. Riparian 3-Layers Present (fraction of reach),
4. Mean Mid-channel Canopy Density (%),
5. Fish Cover,
6. Fast Water Habitat (% riffle and faster),
7. Slow Water Habitat (% glide and pool),
8. Mean Embeddedness--Channel+Margin (%),
9. Substrate Fines -- Silt/Clay/Muck (%),
10. Substrate Sand and Fines -- < 2 mm (%).

These ten metrics were selected because they are comprised of data that is comparable to the data collected and used in calculating the BURP Stream Habitat Index (SHI). EMAP assessments for the various habitat parameters outlined previously in the statewide assessment section were given a rating score of 3 for Good, 2 for Fair, and 1 for Poor. The rating scores for each of the parameters evaluated were then averaged to give an overall CI for the site between 1 and 3. This overall CI was then directly compared to the SHI condition rating. The results of this comparison for all 21 sites can be found in Table 9.

Table 9: Site ratings and support status of sites monitored in 2004 according to BURP and EMAP monitoring data.

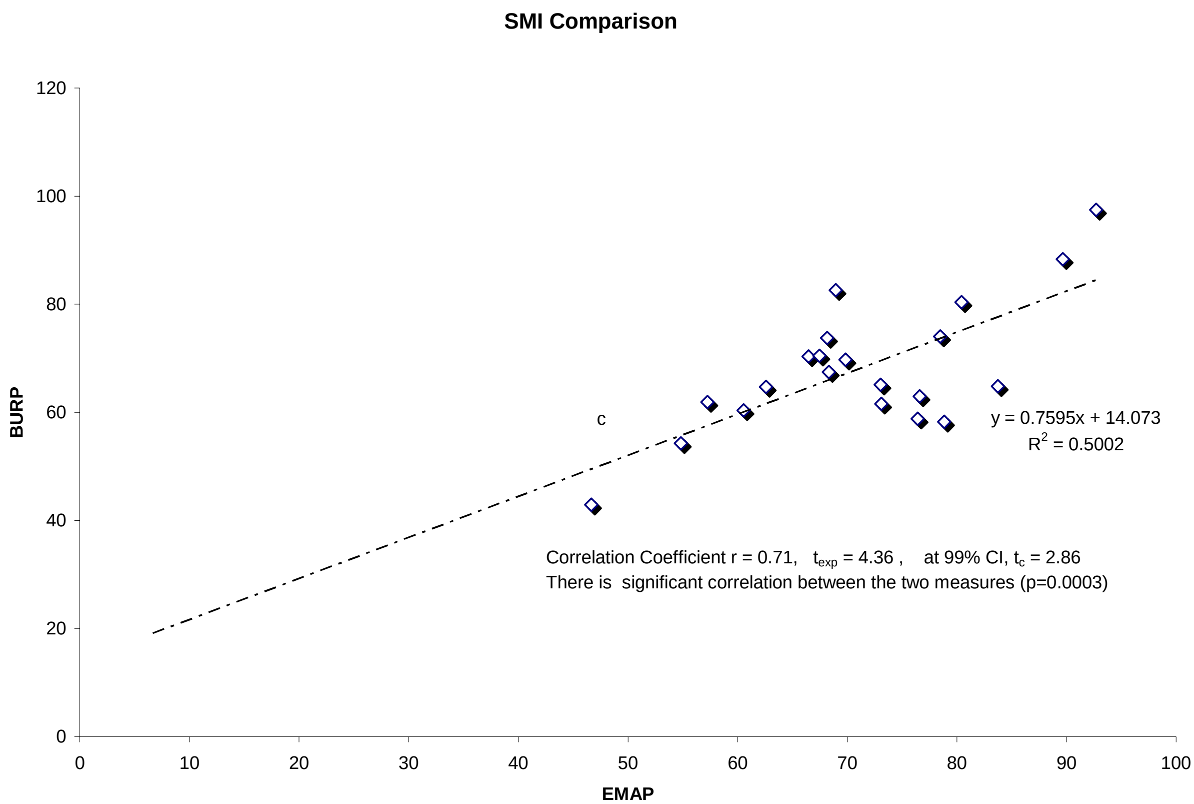
SITENAME	BURP SHI Rating	EMAP PHAB Rating	BURP SMI Rating	EMAP SMI Rating	BURP Score	EMAP Score	BURP Support Status	EMAP Support Status
East Fork Pahsimeroi Riv.	2	2.4	3	2	2.5	2.2	Support	Support
Pahsimeroi Riv.	2	2.1	3	3	2.5	2.55	Support	Support
Lime Creek	1	2.1	3	3	2	2.55	Support	Support
Webber Creek	3	2.2	3	3	3	2.6	Support	Support
Shoshone Creek	1	2.4	2	2	1.5	2.2	NonSupport	Support
St. Joe Riv.	2	2.5	3	3	2.5	2.75	Support	Support
Foehl Creek	3	3	3	3	3	3	Support	Support
Trapper Creek	3	2.8	2	3	2.5	2.9	Support	Support
East Fork Jarbidge Riv.	3	2.7	3	3	3	2.85	Support	Support
Little Piney Creek	3	2.9	3	3	3	2.95	Support	Support
Goose Creek	3	2.5	3	3	3	2.75	Support	Support
West Fork Mink Creek	2	2.7	3	3	2.5	2.85	Support	Support
Bell Marsh Creek	3	2.5	3	3	3	2.75	Support	Support
Moose Creek	3	2.7	3	3	3	2.85	Support	Support
Hoodoo Creek	3	1.8	3	3	3	2.4	Support	Support
Dagger Creek	1	2	3	3	2	2.5	Support	Support
Little Jacks Creek	3	2.7	3	3	3	2.85	Support	Support
Second Fork Squaw Creek	3	2.5	3	3	3	2.75	Support	Support
Deep Creek	3	3	3	3	3	3	Support	Support
Twentymile Creek	2	2.1	2	2	2	2.05	Support	Support
Pahsimeroi Riv.	2	2	3	3	2.5	2.5	Support	Support

PHAB – physical habitat

B.3.3. Macroinvertebrates

Comparing the SMI values for the two protocols indicates significant correlation at the 99% confidence level. The correlation coefficient was 0.71. A paired Student's t-test was done with the experimental t-value being 4.36. This is greater than the critical t-value of 2.86, signifying that there is significant correlation between the two protocols at the 99% confidence level. The linear regression gave a slope of 0.66, which is less than the expected slope of 1 and indicates that the correlation may not be a one to one relationship. There appears to be a slight bias in the correlation, with the EMAP scores tending to be slightly higher than the BURP scores. However, because the monitoring sites selected for this comparison were expected to have low human impact, the dataset may be skewed toward higher macroinvertebrate scores. Additional sites with lower water quality and/or greater human impact would likely have provided SMI scores in the lower quadrant of the plot and would have improved the overall fit of the linear regression.

Figure 15: Correlation of Stream Macroinvertebrate values for samples taken using EMAP protocols versus BURP protocols.



An evaluation of the number of individuals counted in each site showed good correlation with all but one site. This was the Pahsimeroi River site. The sample from the first BURP visit to the site on July 1, 2004, had only 331 individuals, but a repeat visit on August 19, 2004, had a sample with 541 individuals counted. The EMAP visits had counts of 515 on July 27 and 631 on August 17. During the July 1 BURP visit, the stream was experiencing high flow and there was some difficulty in collecting that BURP macroinvertebrate sample.

Of the metrics that make up the SMI, the parameter with the highest correlation coefficient is the Hilsenhoff Biotic Index (a correlation coefficient of 0.90) and the least correlated parameter is the number of scraper taxa (a correlation coefficient of 0.43). Table 10 details the correlation of the individual metrics. As shown, the two metrics with no significant correlation at the 99% confidence level are the percent of taxa in the dominant five taxa groups and the number of scraper taxa. Scatter plots for each of these metrics can be found in Appendix C.

Table 10: Correlation of individual metrics in the Stream Macroinvertebrate Index (SMI)

Metric	Correlation Coefficient	t_{exp}	$>t_c = 2.86$ Significant Correlation
Taxa Richness	0.57	3.00	Significant
Percent in Dominant 5 Taxa Groups	0.43	2.06	Not Significant
HBI	0.94	11.9	Significant
% Plecoptera individuals	0.63	3.51	Significant
# of Ephemeroptera taxa	0.65	3.74	Significant
# of Plecoptera taxa	0.77	5.23	Significant
# of Trichoptera taxa	0.61	3.32	Significant
Clinger Taxa	0.59	3.19	Significant
Scraper Taxa	0.43	2.05	Not Significant

t_{exp} –experimentally calculated Student's T value

t_c – critical Student's T value

B.4. Conclusions

Comparisons of data collected at the same sites using two different protocols show that there is no significant difference between these methods. There is correlation between the macroinvertebrate samples collected even though the EMAP samples collect samples from an area four times the size of the area sampled with BURP methods. There is also no significant difference between the canopy cover measurements made by methods. Habitat evaluation is not directly comparable but the assessment scores were equivalent at 67% of the sites. When habitat and macroinvertebrates were evaluated together, there was only one site with a differing support status determination. If aquatic vertebrates had been evaluated along with habitat and macroinvertebrates, this site would have been determined non-supporting based on the minimum threshold violation in either case.

There appears to be a slight bias in the EMAP score for both habitat and macroinvertebrates that led to a disagreement between the two methods in one case. However, as most of the stream sites evaluated for this study were of high quality waterbodies, this study would benefit from the inclusion of lower quality streams to determine the adequacy of this approach for a broader spectrum of stream ecological condition.

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C. Idaho Rivers EMAP

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C.1. Introduction

C.1.1. Background

This special interest study was part of Idaho's collaboration with EPA in the EMAP-West project. As an area of regional focus, Idaho chose to study rivers to fill a gap in data available to the State for the purpose of assessing ecological condition of the State's waters. Rivers in Idaho are diverse in ecological condition as well as uses such as recreation, navigation, irrigation and habitat for a variety of aquatic vertebrates. Examples of this diversity include the Salmon River that flows through central Idaho, traverses some of the most beautiful and untouched terrain in Idaho, and is the longest free-flowing river contained within a single state. Another example is the Snake River flowing across the southern half of the state and which by the time it leaves Idaho has become a major route of transportation as well as a heavily used supply of irrigation water. This study was designed to monitor and evaluate the condition of these diverse rivers using a statistical probability design similar to the one previously described to select sites for the EMAP-West wadeable streams survey.

This project is a portion of the overall study and was funded through the EPA's EMAP-West project. Results from this study will be used to provide an overall estimate of the ecological condition of Idaho's rivers as well as to help provide tools for the State to use in evaluating the condition of medium and large rivers.

C.1.2. Purpose

The objectives of this study were three-fold:

1. To define least-impacted condition for rivers;
2. To develop a set of tools for use in assessing river ecological condition;
3. To determine the overall estimated condition of Idaho's large rivers.

Selecting a set of least-impacted reference sites provided a standard for developing a set of tools predictive of river ecological condition. These tools were then used to estimate overall river ecological condition and individually the condition of physical habitat, water chemistry, and macroinvertebrate community. These tools provide a method to assess river ecological condition in future surveys, and the findings of future surveys will serve to further refine these tools.

C.1.3. Special Interest Area

The special interest area defined for this study is medium to large rivers within the state of Idaho excluding portions of the Snake River that are considered a "great" river and will be included in a different study. The study evaluated 6006 km of rivers within Idaho. IDEQ follows its water body size criteria (Grafe et al. 2002) to ensure that streams are large enough for the study. Specifically, the selected streams must meet at least <u>two</u> of the following three criteria: 1) fifth order or larger, 2) 15 meters or greater in wetted width, and/or 3) an average depth greater than 0.4 meters. The study area is a large geographic area that involved intense logistic planning and coordination with multiple agencies (United States Forest Service [USFS], Idaho Fish and Game, EPA Region 10, EPA Office of Research and Development – Corvallis, and regional IDEQ offices).

C.2. Methods

Sample design and analysis of survey data were done using the open source statistics language R version 2.2.1 (2005) and R package spsurvey (http://cran.r-project.org/web/packages/spsurvey/), a group of functions that implements algorithms required for design and analysis of EMAP probability surveys.

C.2.1. Sample Design

The target population for the survey was initially all perennial waters within Idaho coded as 5th Strahler order (Strahler 1957) or greater. This range of Strahler order was based on experience in the EMAP-West project that approximately 10% of 4th order streams and rivers were determined to be boatable. The final target population was rivers of non-wadeable size in Idaho as determined by the Idaho Waterbody Size Criteria (Grafe, C.S. 2002b; 2002a), excluding great rivers.

In response to a perceived excess of Snake River sites in the random sample drawn, one primary site (#25, near Hagerman) and three oversample sites (#46, near Register Rock; #86, near Rose; #110, west of Lake Walcott) were skipped. These sites were replaced with four oversample sites from the Southern Basins bioregion (#103, Weiser River in Weiser; #115 Snake River near Walters Butte; #130 Portneuf River near Lava Hot Springs; #131 Payette River in Emmett). To account for this deviation from the sample design, design weights were adjusted to estimate the extent and ecological condition for the Snake River bioregion, the Southern bioregion omitting the Snake River, the Central bioregion omitting the Snake River, and the Northern bioregion. Stream lengths in kilometers were 732.3 for the Snake River, 3139.3 for the Southern bioregion omitting 661.1 km of Snake River, 1407.4 for the Central bioregion omitting 71.2 km of Snake River, and 1211.7 for the Northern bioregion. For inference to the Snake River, the skipped sites were assumed to be missing at random on the Snake River.

The probability sample of stream sites was selected using an unequal probability random tessellation stratified design with an oversample as described in Stevens and Olsen (1999) and Stevens (1997). This design spatially-balances the sample to ensure spatial coverage of the sample is similar to the spatial coverage of the target population (Grafe, C.S. 2002a), excluding great rivers. A sample size of 50 sites was initially selected to provide an estimate of the overall condition for rivers in Idaho.

C.2.2. Stream Survey

River sites were surveyed according to the EPA manual for non-wadeable rivers (Peck et al. 2005a). A short synopsis of the method is included here. For more information please refer to the above cited reference.

Each river site was divided into 11 transects that were spaced apart by a distance equal to roughly 4 times the channel width. The overall reach length of the site was 40 times the channel width. According to work done early on in the study this was determined to be the most effective reach length (Maret et al. 2004). At each of these transects samples of periphyton and benthic macroinvertebrate communities and measures of the physical habitat were taken. The physical habitat measures were a mix of physical measures of the river channel such as depth, wetted width, presence of islands or bars, and substrate type and dominance with subjective assessment of various parameters developed to get to a measure of the overall anthropogenic influences. Benthic macroinvertebrate samples were collected from the substrate in flowing water 1 meter in depth using a D-frame kicknet. Periphyton samples were taken from flat rocks collected from a sunny area of the transect. The rocks were scrubbed using a brush and delimiter, washing the material through a funnel into the collection jar. Benthic macroinvertebrate and periphyton samples were composited from all transects to create the final sample.

At the end of each reach a plankton tow was done from the rear of the boat. This sample was processed and sent to the lab with chemistry samples; water chemistry samples were taken at the end of the reach to allow for time to ship samples to the lab (samples had a 24 hour holding time). Water chemistry samples included one 4-liter water sample and two 60-mL syringes collected and capped to prevent exposure to air during shipping. These samples were analyzed for pH and dissolved oxygen. Other parameters analyzed can be found in the non-wadeable field manual (Peck et al. 2005a). In situ monitoring of conductivity, dissolved oxygen, and stream temperature was also conducted.

Field data was recorded on field forms. Copies of these field forms are stored at the Idaho Department of Environmental Quality State Office (1410 N. Hilton, Boise, ID). The original field forms were sent to EPA Region 10 and data was uploaded into the Surface Water Information Management Database (SWIM). Data was then downloaded for the purposes of this study and imported into Microsoft Access.

C.3. Selecting Reference Sites

This study evaluated two methods for selecting a subset of least-impacted reference sites from the surveyed sites. Establishing least-impacted status for sites provides a standard against which survey metrics can be evaluated for sensitivity to detect impairment, and this information guides the development of multi-metric indices of ecological health. This least-impacted site approach has been used in many other studies (Bailey et al. 2004; Boulton 1999; Grafe 2004; Herlihy et al. 2005; Karr 1999; Maddock 1999; Turak et al. 1999) and is currently the approach used by Idaho in its assessment of wadeable streams (Grafe 2004; Grafe et al. 2002).

The first method was based on site-survey water chemistry and physical habitat data. This method was similar to that used to select reference condition in the EMAP-West wadeable streams. The second method was based on an evaluation of GIS metrics developed from watershed characteristics. This method is similar to that used in the Region 10 State Assessments and in Idaho’s selection of reference condition for wadable streams (Lattin et al. 2004). Both methods were guided by best professional judgment to select least-impacted reference sites. Recent evaluation of classifying least-impacted sites suggest that a combination of field data and geographic information be used to critically review those sites selected as least-impacted (Whittier et al. 2007)

For both methods, classification of site status was done using a combination of cluster analysis and best professional judgment. Cluster analysis and best professional judgment are both supported by EPA for identifying reference sites for streams and small rivers (EPA 1996). The classification method was K-medoid cluster analysis (Kaufman et al. 1990) with the partitioning around medoids (PAM) algorthm. The K-medoid method was chosen for its robustness to misclassification relative to the better know alternative K-means cluster analysis. Cluster analysis of site metrics principal components was run (Krzanowski et al. 1994a; 1994b). Principal components analysis transforms a set of correlated variables into a set of new uncorrelated variables called principal components. The first principal component accounts for as much variability in the data as possible and each succeeding component accounts for as much of the remaining variability as possible. Each principal component is a linear combination of the original variables. Ideally a small number of principal components account for most of the variability in the data. An advantage to this approach is that classification can be based on information from all explanatory variables even if there are more explanatory variables than observations. Site metrics were measured on very different scales, but, in general, metrics were considered equally important. To avoid having an arbitrary choice of measurement unit influence the structure of the principal components, principal components were extracted from the correlation matrix.

C.3.1. Site-Survey water chemistry and physical habitat metrics

Survey metrics from the 2002-2004 REMAP field seasons included both water chemistry and physical habitat metrics.

Water chemistry metrics were ammonium, anion deficit, calcium, calculated alkalinity, calculated bicarbonate, calculated carbonate, calculated conductivity, chloride, closed headspace pH, color, conductivity, Debye-Huckel-Onsager calculated conductivity, dissolved inorganic carbon, dissolved organic carbon, dissolved selenium, dissolved zinc, estimated organic anion, gran ANC (acid neutralizing capacity), H+ from closed headspace pH, hydroxide from closed headspace pH, ion balance, ionic strength, magnesium, nitrate, potassium, silica, sodium, sulfate, sum of anions, sum of base cations, sum of cations, total nitrogen, total phosphorus, total suspended solids, and turbidity.

Physical habitat metrics included stream temperature and measures of channel morphology, channel cross section and bank morphology, fish cover, human disturbance, large woody debris, relative bed stability, residual pool, riparian vegetation, and substrate.

C.3.2. GIS metrics

Metrics potentially predictive of site impact status were developed from characteristics of the drainages upstream of site (bank transect A) but within the same USGS 4th field/8-digit hydrologic unit code (HUC). 6th field/12 digit HUCs were considered in the delineation of drainage areas, but these areas were determined to be too small to adequately evaluate upstream influences. The upstream drainage area for each site within the USGS 4th field/8-digit HUC was delineated using the Hydrology tools in the Spatial Analyst extension for ArcView 9.2 and the National Elevation Dataset 30 meter for Idaho (PRISM data set for 1971-2000). For sites less than 4 miles from the upstream HUC boundary, the drainage was defined to include the next upstream HUC.

Several sites were less than 4 miles from the upstream HUC boundary. The drainages for these sites were expanded to include the next upstream HUC. The Clearwater River site near Kamiah (#056) was within 4 miles of the confluence of upstream HUCs , 17060304 and 17060305; both upstream HUCs were included in the drainage for this site. The Salmon River site near MacKay Bar (#055) was at the confluence of two HUCs (17060207 and 17060208); therefore the combined drainage was used.

Some HUCs contained multiple sites, therefore some site drainage areas overlapped. The calculated drainage areas were compared to the external boundaries of the 4th field/8-digit HUC boundaries delineated in the Idaho Watersheds 5th and 6th field unit data set published by the Idaho Department of Water Resources (Inside-Idaho 2006) and were corrected to match these where discrepancies existed. A number of the drainage areas extended beyond the state boundary and for these sample locations the area within and outside the state was calculated. The resulting data set was a polygon shapefile containing a polygon representing the upstream drainage area for each sample location. These polygons were then used to develop metrics that described characteristics of the drainage area of the survey sites.

To represent general anthropogenic disturbance, developed open space (%), developed low intensity (%), developed medium intensity (%), developed high intensity (%), pasture/hay (%), and cultivated crops (%) metrics were created from National Land Cover Database (NLCD) coverages (U.S.G.S. 2001)

To represent more specific anthropogenic disturbances, metrics were created for road density (miles per square mile), railroad density, roadless area (%), special designated area (%), and roadless plus special designated area (%), mine density (mining permits per square mile), dairy density (dairies per square mile), waste water land application [WWLA] area (%), agriculture on steep slopes area (% area with agriculture on greater than 10 degree slope), recreation density (recreation sites per square mile), dam density (dams per square mile), large dam density, intermediate dam density, small dam density, dam storage capacity density (acre-feet per square mile), and dam storage area (%). Large dams were those having height 40 feet or greater or stores 4,000 acre-feet or more. Medium dams were those having height greater than 20 feet and less than 40 feet or stores 100 acre-feet or more but less than 4,000 acre-feet. Small dams were those having height 20 feet or less and stores less than 100 acre-feet.

Mean precipitation, burn-within-5-years area (%), and National Forest (%) metrics were also included.

All GIS coverages were published by either State of Idaho or United States government agencies/projects: Idaho Department of Environmental Quality, Idaho Department of Water Resources, Interior Columbia Basin Ecosystem Management Project, United States Department of Commerce, United States Department of Agriculture Forest Service, United States Geological Survey, and United States Bureau of Land Management. Many of these coverages were downloaded from INSIDE Idaho (Inside-Idaho 2006).

C.4. Index Development

Multi-metric indices were developed, using the method of Barbour et al (Barbour et al. 1996), to assess the overall river ecological condition and individually the condition of physical habitat, water chemistry, and macroinvertebrate community. As the names implies, a multi-metric index combines information from multiple survey metrics. For example, a multi-metric index of macroinvertebrate condition combines information from a set of macroinvertebrate survey metrics sensitive to detecting impairment.

Metrics were screened for sensitivity to impairment. Sensitivity was based on the degree of separation between boxplots for the reference and moderately/highly-impacted groups. Metrics with high sensitivity have the most potential to be good predictors of impairment status. From most sensitive to least sensitive, a metric was scored 3 if there was no overlap of interquartile ranges, 2 if there was some overlap of interquartile ranges but both medians were outside the interquartile range, 1 if there was moderate overlap of interquartile ranges but at least 1 median was outside the interquartile range overlap, and 0 if either one interquartile was contained in the other or the overlap contained both medians.

Metrics were also screened for sensitivity by bioregion. Consistent sensitivity across bioregions was desired so that resulting indices would be applicable statewide. Sensitive metrics were also screened for similarity in least-impacted distribution across bioregions.

Each metric was scored for all survey sites based on percentiles of the reference distribution. Metrics that increase in value with impairment were scored 1 for site values greater than the reference maximum, 3 for site values greater than the 75th percentile but less than or equal to the maximum, and 5 for site values less than or equal to the 75th percentile. Metrics that decrease in value with impairment were scored 1 for site values less than the reference minimum, 3 for site values less than the 25th percentile but greater than or equal to the minimum, and 5 for site values greater than or equal to the 25th percentile. One metric, pH, deneutralizes in value with impairment. Therefore, metric score was 1 for pH greater than the reference maximum, 3 for greater than the 87.5th percentile but less than or equal to the maximum, and 5 for less than the 87.5th percentile. Penalties for low pH were considered, but the reference minimum and 12.5th percentile were not low enough to provide meaningful scoring bands to penalize low pH scores.

The multi-metric index for a site was the sum of metric scores. Many indices can be developed from one set of survey metrics. Candidate metrics were compared by ability to discriminate between reference and non-reference sites.

C.4.1. Water Chemistry and Physical Habitat

The Idaho River Physiochemical Index (RPI) has been proposed as a tool to assess large river condition in Idaho (Grafe, C. S. 2002). This index is a modification of the Oregon Water Quality Index (Cude 1998). The RPI was consistent with IDEQ employees' professional opinions of river status and was significantly associated with percent agriculture in 5th field watershed. The RPI is based on water temperature, dissolved oxygen, pH, total solids, ammonia+nitrate nitrogen, total phosphorus, and fecal coliform bacteria.

C.4.2. Macroinvertebrates

The River Macroinvertebrate Index (RMI), Idaho's current macroinvertebrate index, was calculated for REMAP sites to evaluate the index's performance at new sites. The RMI consists of 5 metrics: *number of taxa* (TOTLRICH), *number of ephemeroptera, plecoptera, and trichoptera taxa* (EPTRICH), *percent dominant taxon individuals* (DOM1PIND), *percent family elmidae individuals* (PCTELMI), and *percent of individuals in predator functional feeding groups* (PCTPRED). TOTLRICH, EPT_RICH, PCTELMI, and PCTPRED are expected to decrease with impairment. DOM1PIND is expected to increase with impairment. TOTLRICH, EPTRICH, and DOM1PIND are standard REMAP macroinvertebrate metrics. PCTPRED was calculated for REMAP sites using a predator/non-predator look-up table created from the taxonomy table used in the RMI study. Functional feeding group was available for 485 genera of which 149 were predator and 336 were non-predator. Counts for unmatched REMAP genera were excluded. PCTELMI was calculated using REMAP taxonomic family and abundance. RMI metrics were scored by percentiles of REMAP reference distributions to adjust for differences in survey protocols. The RMI scores PCTPRED 3 or 5 but not 1 due to weak discrimination in the data set used to develop the RMI. This restriction was used in reproducing the RMI for REMAP sites.

A second index based upon metrics selected from the host of metrics provided by EPA was developed. This index was based upon three metrics: Ephemeroptera, Plecoptera and Trichoptera Richness (EPTRICH), percent of individuals that are non-insects (NOINPIND) and percent of individuals that were Plecoptera (PLECPIND). Correlations with EPTRICH were -0.67 (NOINPIND) and 0.80 (PLECPIND). Correlation between NOINPIND and PLECPIND was -0.47. This index was evaluated against the RMI for its ability to distinguish least-impacted from moderately and highly impacted sites.

C.5. Results

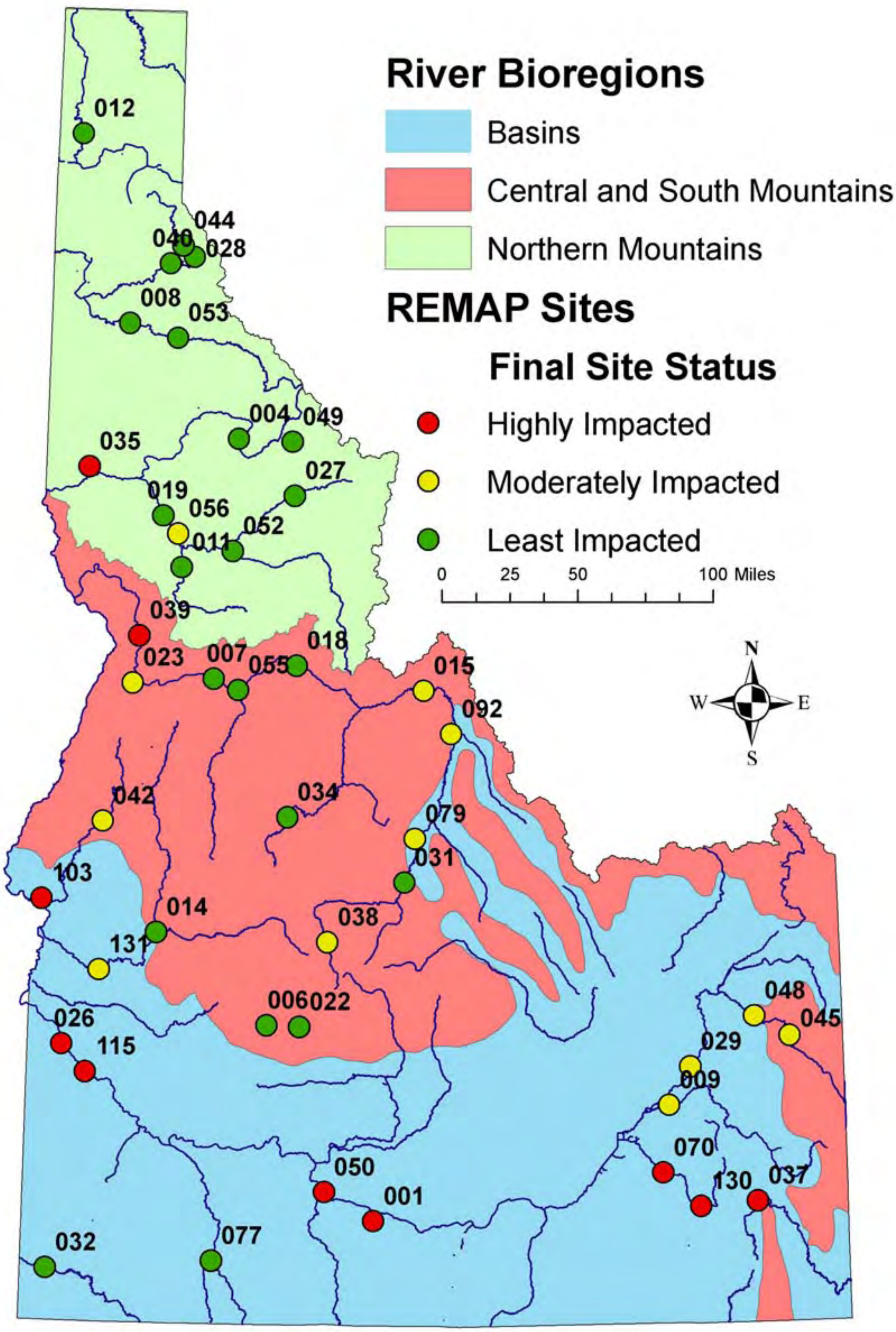
A total of 47 primary and oversample sites were surveyed (Table 11).

Table 11: Sites surveyed for the Idaho Rivers Regional EMAP study.

Site ID	Site Name	Site ID	Site Name
IDW02353-001	Rock Creek	IDW02353-035	Potlach River
IDW02353-003	Salmon River	IDW02353-037	Bear River
IDW02353-004	North Fork Clearwater River	IDW02353-038	Salmon River
IDW02353-006	South Fork Boise River	IDW02353-039	Salmon River
IDW02353-007	Salmon River	IDW02353-040	Coeur D'Alene River
IDW02353-008	St. Joe River	IDW02353-042	Weiser River
IDW02353-009	Blackfoot River	IDW02353-044	Coeur D'Alene River
IDW02353-010	Middle Fork Salmon River	IDW02353-045	Snake River
IDW02353-011	South Fork Clearwater River	IDW02353-048	Snake River
IDW02353-012	Priest River	IDW02353-049	Kelly Creek
IDW02353-014	Payette River	IDW02353-050	Snake River
IDW02353-015	Salmon River	IDW02353-052	Selway River
IDW02353-017	Big Lost River	IDW02353-053	St. Joe River
IDW02353-018	Salmon River	IDW02353-055	Salmon River
IDW02353-019	Clearwater River	IDW02353-056	Clearwater River
IDW02353-022	South Fork Boise River	IDW02353-070	Portneuf River
IDW02353-023	Little Salmon River	IDW02353-077	West Fork Bruneau River
IDW02353-026	Snake River	IDW02353-079	Salmon River
IDW02353-027	Lochsa River	IDW02353-092	Salmon River
IDW02353-028	Coeur D'Alene River	IDW02353-103	Weiser River
IDW02353-029	Snake River	IDW02353-115	Snake River
IDW02353-031	Salmon River	IDW02353-130	Portneuf River
IDW02353-032	Owyhee River	IDW02353-131	Payette River
IDW02353-034	Middle Fork Salmon River		

Table 11 shows the location of the sites surveyed. In 2002, 16 sites were surveyed in the Southern Basins bioregion. In 2003, 14 sites were surveyed in the Northern Mountains bioregion. In 2004, 17 sites were surveyed in the Central and Southern Mountains bioregion.

Figure 16: Idaho Rivers Regions EMAP Sites monitored from 2002 through 2004.



C.5.1. Site Classification

C.5.1.1. Site-Survey method

Two sites were omitted from the site-survey method of classification based on surveyed physical habitat and water chemistry metrics. The Middle Fork of the Salmon River site near Aparejo Point (#010) was surveyed too soon after a storm event. The Salmon River site near Deadhorse Ridge (#003) had no water chemistry data and had missing values for many physical habitat metrics. The resulting sample size was 44.

Sites were first classified by impact status using only water chemistry metrics. Classifications from cluster analysis of principal components of water chemistry metrics were modified by expert judgment to produce a preliminary site impact status list. Clusters were highly interpretable for 2, 3, and 4 cluster solutions. The 2-cluster solution was interpreted as eight highly-impacted and thirty-six moderately and least-impacted sites. The highly-impacted cluster split, in the 3-cluster solution, into clusters of three and five which corresponded geographically with the Bear/Portneuf and middle Snake/lower Weiser drainages, respectively. The moderately and least-impacted cluster remained unchanged in the 3-cluster solution, but, in the 4-cluster solution, split into clusters of eleven moderately-impacted sites and twenty-five least-impacted sites.

With respect to the 4-cluster solution, 4 classifications disagreed with expert judgment. Three sites classified as least-impacted were assigned moderately-impacted status based primarily on total nitrogen concentration: Payette River downstream of Emmett (#131, 243 ug/L), Clearwater River near Stites (#011, 208 ug/L), and Little Salmon River near Riggins (#023, 191 ug/L). The Potlach River near Juliaetta (#035), classified as moderately-impacted, was assigned highly-impacted status based on pH (9.25).

The first, second, third and fourth principal components accounted for, cumulatively, 62%, 72%, 81%, and 87% of the variability observed in the water chemistry data. The first principal component had large contributions from conductivity and metrics highly correlated with conductivity; fifteen metrics that had pairwise linear correlation 0.90 or higher with conductivity and ten more with correlation between 0.5 and 0.9. The second principal component had a large contribution from pH and total phosphorus. The third principal component had large contributions from pH, total suspended solids, and turbidity. The fourth principal component had a large contribution from total nitrogen. While all metrics make at least some contribution to each principal component, the proportion of variance explained with a small number of principal components suggested that it might be possible to develop a simple classification rule.

Final site impact status based on water chemistry and best professional judgment can be reproduced with the following rule: sites with total nitrogen greater than 320 are highly-impacted; remaining sites with total nitrogen greater than 160 or conductivity greater than 200 are moderately-impacted, and all other sites are least-impacted.

More generally, final site impact status based on water chemistry and best professional judgment was also consistent with the following rule: sites with total nitrogen greater than 320, total phosphorus greater than 160, conductivity greater than 400, or pH greater than 9.00 were highly-impacted; sites with total nitrogen between 160 and 320, total phosphorus between 80 and 160, conductivity between 200 and 400 were moderately-impacted; all other sites were least-impacted.

Means for conductivity, total nitrogen, total phosphorus, and pH by cluster are listed in Table 12. Sites in highly-impacted Cluster 1 had the highest mean total nitrogen (1424 μg/L) and high mean conductivity (487.2 μS/cm^2). Sites in highly-impacted Cluster 2 had the highest mean conductivity (760.0 μS/cm^2) and high mean total nitrogen (524 μg/L). Sites in moderately-impacted Cluster 3 had elevated mean conductivity, total nitrogen, total phosphorus, and pH relative to means for least-impacted Cluster 4.

Table 12: Mean values of metrics in the 4-cluster solution based on principal components of water chemistry metrics.

Cluster	Cluster Interpretation	Conductivity (μS/cm^2)	pH	Total Nitrogen (μg/L)	Total Phosphorus (μg/L)
1	highly-impacted	487.2	8.65	1424	90
2	highly-impacted	760.0	8.37	524	31
3	moderately-impacted	238.2	8.62	215	17
4	least-impacted	84.2	8.26	105	8

Inclusion of physical habitat metrics did not improve agreement between classification based on water chemistry alone and expert judgment. Therefore, final site impact status (Table 13 and Figure 16) was based on the 4-cluster water chemistry classifications modified by expert judgment.

Classification based on physical habitat metrics alone was less successful. While classifications were in general agreement with those based on water chemistry, clusters were relatively weak and in relative disagreement with expert judgment. Attempts to improve cluster solutions using subsets of physical habitat metrics were not successful. Physical habitat metrics that showed potential for classification purposes included percent of reach with fast water, sum of riparian disturbances (agricultural and non-agricultural), and four areal proportions in the littoral zone: proportion filamentous algae cover, proportion aquatic macrophyte cover, proportion overhanging vegetation, proportion fish cover (boulders).

When cluster analysis including stream temperature with water chemistry metrics was performed there were 5 classifications in disagreement with the classifications from water chemistry alone. Of the five classifications, three disagreed with best professional judgment and two agreed with best professional judgment. The moderately-impacted Salmon River site (#038, 16.0° C) was incorrectly classified least-impacted. Two least-impacted sites, Clearwater River near Six Mile Creek (#019, 24.5° C) and Selway River (#052, 21.8° C), were incorrectly classified moderately-impacted. The South Fork Clearwater River site (#011, 23.7° C) and the Payette River site (#131, 22.2° C) were correctly classified as moderately-impacted

Overall, stream temperature as measured in this survey was of limited value for number of reasons. First, stream temperature was missing for the Little Salmon River site (#023). Second, the nine highest stream temperatures were taken after 2:45 pm (time of day ranged from 10:00 am to 7:15 pm). Third, stream temperature varied greatly for neighboring sites within the same drainage. For example, the Clearwater River site near Kamiah (#056) had a relatively low stream temperature (16.5° C), but, approximately 10 miles downstream and without a major confluence in between, the stream temperature at the Clearwater River site near Sixmile Creek (#019) was 24.5° C. All sites upstream of Kamiah also had relatively high stream temperature: 23.7° C at South Fork of the Clearwater site (#011); 21.8° C at Selway River site (#052); 24.4° C at Lochsa River site (#027).

Table 13: Site impact status based on cluster analysis of water chemistry and expert judgment. Site is identified by stream name, 24,000:1 United States Geological Survey map name, and site identification number. Neighbor is a site's nearest neighbor cluster. Silhouette width measures how well a site was clustered with larger values indicating better clustering. Clusters were interpreted as either highly-impacted (H), moderately-impacted (M), or least-impacted (L). Several sites were reclassified based on expert judgment.

				Site impact status	
Site	Cluster	Neighbor	Silhouette Width	Cluster Interpretation	Expert Judgement
Snake R (Thousand Springs) (050)	1	2	0.19	H	
Snake R (Walters Butte) (115)	1	3	0.18	H	
Rock Cr (Twin Falls) (001)	1	2	0.05	H	
Weiser R (Weiser South) (103)	1	3	-0.01	H	
Snake R (Opalene Gulch) (026)	1	3	-0.05	H	
Portneuf R (Lava Hot Springs) (130)	2	1	0.34	H	
Bear R (Alexander) (037)	2	1	0.29	H	
Portneuf R (Pocatello South) (070)	2	1	0.25	H	
Blackfoot R (Blackfoot) (009)	3	4	0.35	M	
Snake R (Firth) (029)	3	4	0.29	M	
Salmon R (Salmon) (092)	3	4	0.28	M	
Salmon R (Challis) (079)	3	4	0.28	M	
Owyhee R (Red Basin) (032)	3	4	0.24	M	
Salmon R (Ulysses Mountain) (015)	3	4	0.24	M	
Snake R (Wheaton Mountain) (045)	3	4	0.12	M	
Potlach R (Juliaetta) (035)	3	4	0.10	M	H
Snake R (Heise) (048)	3	4	0.08	M	
Weiser R (Goodrich) (042)	3	4	-0.01	M	
Salmon R (Obsidian) (038)	3	4	-0.15	M	
Clearwater R (Kamiah) (056)	4	3	0.53	L	
Coeur d'Alene R (Pond Peak) (044)	4	3	0.52	L	
Coeur d'Alene R (Prichard) (028)	4	3	0.51	L	
Kelly CR (Scurvy Mountain) (049)	4	3	0.51	L	
Lochsa R (Greystone Butte) (027)	4	3	0.51	L	
Salmon R, M FK (Artillery Dome) (034)	4	3	0.49	L	
Priest R (Prater Mountain) (012)	4	3	0.48	L	
St Joe R (Saint Joe Baldy) (008)	4	3	0.48	L	
Boise R, S FK (Featherville) (006)	4	3	0.47	L	
Payette R (Banks) (014)	4	3	0.46	L	
St Joe R (Marble Creek) (053)	4	3	0.45	L	
Clearwater R (Sixmile Creek) (019)	4	3	0.43	L	
Boise R, S FK (Jumbo Mountain) (022)	4	3	0.41	L	
Clearwater R, N FK (Clarke Mountain) (004)	4	3	0.40	L	
Coeur d'Alene R (Grizzly Mountain) (040)	4	3	0.38	L	
Salmon R (MacKay Bar) (055)	4	3	0.37	L	
Salmon R (Cottontail Point) (007)	4	3	0.33	L	
Clearwater R, S FK (Stites) (011)	4	3	0.29	L	M
Salmon R (Sheep Hill) (018)	4	3	0.27	L	
Little Salmon R (Riggins) (023)	4	3	0.26	L	M
Bruneau R, W FK (Indian Hot Springs) (077)	4	3	0.22	L	
Salmon R (Slate Creek) (039)	4	3	0.22	L	
Selway R (Lowell) (052)	4	3	0.21	L	
Payette R (Northwest Emmett) (131)	4	3	0.20	L	M
Salmon R (Bald Mountain) (031)	4	3	0.17	L	

C.5.1.2. GIS

GIS-based classification was compared to site impact status based on water chemistry and best professional judgment. Cluster analysis based on all GIS metrics was relatively unsuccessful. To protect against spurious agreement due to data fishing, a second cluster analysis on GIS metrics was limited to using only a subset of six metrics considered to be the most broadly descriptive of disturbance. These metrics were based on the following NLCD land cover databases: *developed open space, developed low intensity, developed medium intensity, developed high intensity, pasture/hay,* and *cultivated crops*.

Classifications from the cluster analysis based on the six NLCD metrics agreed strongly with site impact status based on water chemistry and expert judgment. GIS correctly identified all but two sites considered least-impacted by water chemistry and expert judgment. These two sites, Clearwater River near Six Mile Creek (#19) and Clearwater near Kamiah (#56), had the 2nd and 8th highest *percent crop area,* respectively. One possible explanation for the inconsistent relationship between water chemistry and *percent crop area* is that this metric doesn't differentiate between dry land farming, common in this area, and irrigated farming. Two sites classified as least-impacted by GIS, Clearwater River near Stites (#11) and Owyhee River near Red Basin (#32), were moderately-impacted according to water chemistry and expert judgment. The Snake River at Firth (#29) was classified by GIS as highly-impacted instead of moderately-impacted by chemistry and expert judgment. Four sites were classified as moderately-impacted instead of highly-impacted (Snake River near Walter Butte, #115; Snake River near Opalene Gulch, #26; Bear River near Alexander, #37; Weiser River near Weiser, #103).

Overall, classification based on the six NLCD land cover metrics correctly classified 91% (20/22) of the sites considered least-impacted based on water chemistry and expert judgment. Percent correctly classified for the moderately-impacted and highly-impacted groups were 77% (10/13) and 56% (5/9), respectively. Percent accuracy was 80% (35/44). Percent accuracy for classifying least-impacted versus a combined moderately/highly-impacted group was 91% (40/44). Overall, classification based on the six NCLD land cover metric suggests great potential to predict least-impacted condition (as defined in this study) but limited potential to distinguish between moderately-impacted and highly-impacted conditions.

In subsequent attempts to improve site impact classification, cluster analyses were free to consider many possible combinations and transformations of GIS metrics. Of the models considered, the cluster solution with the greatest agreement with site impact status based on water chemistry and expert judgment was from use of a subset of five metrics: *developed open space, pasture/hay area, cultivated crops area, dam storage capacity density,* and *dam storage area*. This solution had only five classifications in disagreement. The Clearwater River near Kamiah (#56) and the Salmon River near Bald Mountain (#31) sites were classified as moderately-impacted instead of least-impacted. One cluster had three sites each of which had a different site impact status based on water chemistry and expert judgment (Clearwater River near Six Mile Creek, #19; Snake River near Firth, #29; Potlach River near Juliaetta, #35). These results suggest that there is potential to improve classification based on metrics developed from GIS.

Table 14: Site impact classification based on GIS and comparison to final site impact status based on water chemistry and best professional judgment.
Site is identified by stream name, 24,000:1 United States Geological Survey map name, and site identification number. Neighbor is a site's nearest neighbor cluster. Silhouette width measures how well a site was clustered with greater values indicating better clustering. Cluster Interpretation is the interpretation of GIS clusters as highly-impacted (H), moderately-impacted (M), or least-impacted (L). Final Status is tabled for GIS classifications that disagree with final impact status based on water chemistry and expert judgment.

				Site impact status	
Site	Cluster	Neighbor	Silhouette Width	Cluster Interpretation	Final Status
Snake R (Firth) (029)	1	2	0.04	H	M
Snake R (Thousand Springs) (050)	1	2	0.03	H	
Rock Cr (Twin Falls) (001)	1	2	-0.08	H	
Potlach R (Juliaetta) (035)	2	3	0.62	H	
Portneuf R (Pocatello South) (070)	2	3	0.60	H	
Clearwater R (Sixmile Creek) (019)	2	3	0.55	H	L
Portneuf R (Lava Hot Springs) (130)	2	3	0.55	H	
Snake R (Walters Butte) (115)	3	4	0.34	M	H
Little Salmon R (Riggins) (023)	3	4	0.31	M	
Snake R (Opalene Gulch) (026)	3	4	0.31	M	H
Salmon R (Ulysses Mountain) (015)	3	4	0.26	M	
Bear R (Alexander) (037)	3	4	0.26	M	H
Weiser R (Weiser South) (103)	3	4	0.16	M	H
Salmon R (Salmon) (092)	3	4	0.05	M	
Payette R (Northwest Emmett) (131)	3	4	0.03	M	
Clearwater R (Kamiah) (056)	3	4	-0.12	M	L
Weiser R (Goodrich) (042)	3	4	-0.14	M	
Salmon R (Challis) (079)	3	4	-0.24	M	
Blackfoot R (Blackfoot) (009)	3	4	-0.24	M	
Snake R (Heise) (048)	3	4	-0.32	M	
Salmon R (Obsidian) (038)	3	4	-0.45	M	
Snake R (Wheaton Mountain) (045)	3	4	-0.46	M	
Salmon R (MacKay Bar) (055)	4	3	0.91	L	
Boise R, S FK (Jumbo Mountain) (022)	4	3	0.91	L	
Boise R, S FK (Featherville) (006)	4	3	0.91	L	
Selway R (Lowell) (052)	4	3	0.91	L	
Coeur d'Alene R (Pond Peak) (044)	4	3	0.91	L	
Salmon R (Sheep Hill) (018)	4	3	0.91	L	
Clearwater R, N FK (Clarke Mountain) (004)	4	3	0.91	L	
Salmon R (Cottontail Point) (007)	4	3	0.91	L	
Coeur d'Alene R (Prichard) (028)	4	3	0.91	L	
Kelly CR (Scurvy Mountain) (049)	4	3	0.91	L	
Coeur d'Alene R (Grizzly Mountain) (040)	4	3	0.90	L	
Salmon R, M FK (Artillery Dome) (034)	4	3	0.90	L	
Priest R (Prater Mountain) (012)	4	3	0.89	L	
Bruneau R, W FK (Indian Hot Springs) (077)	4	3	0.88	L	
St Joe R (Marble Creek) (053)	4	3	0.87	L	
Payette R (Banks) (014)	4	3	0.87	L	
St Joe R (Saint Joe Baldy) (008)	4	3	0.86	L	
Clearwater R, S FK (Stites) (011)	4	3	0.82	L	M
Lochsa R (Greystone Butte) (027)	4	3	0.80	L	
Owyhee R (Red Basin) (032)	4	3	0.79	L	M
Salmon R (Bald Mountain) (031)	4	3	0.75	L	
Salmon R (Slate Creek) (039)	4	3	0.72	L	

C.5.2. Chemistry and Physical Habitat

Water chemistry and physical habitat metrics were evaluated for the ability to detect impairment (sensitivity). Metrics were screened for consistent sensitivity across bioregions and similar least-impacted distributions across bioregions. With only one least-impacted site in the Southern bioregion and two moderately/highly-impacted sites in the Northern bioregion, these screens provided limited information.

Twenty-six water chemistry metrics had sensitivity of 3, four had sensitivity of 2, and three had sensitivity of 1. Most water chemistry metrics with sensitivity of 3 were highly correlated with conductivity (Table 15).

Water chemistry indices were developed from sets of metrics with moderate pairwise correlations (<0.75). The final water chemistry index consisted of four metrics: *conductivity*, *pH*, *total nitrogen*, and *total phosphorus*. Each metric had similar reference distributions by bioregion and consistent sensitivity by bioregion. The reference minimum and 12.5 percentile for pH were not low enough to provide meaningful scoring band to penalize low pH scores (Table 21). Possible values of the water chemistry index range from 4 to 20. Good condition ratings were assigned to sites with index scores greater than or equal to 16. Fair condition ratings were assigned to sites with index scores from 12 to 14. Poor condition ratings were assigned to sites with index scores less than or equal to 10.

Physical habitat metrics were evaluated for sensitivity to detect impairment (Table 17). Metrics with missing values or too few unique values (e.g., all zeros or almost all zeros) have been omitted from Table 17.

Of the eight metrics with high sensitivity, *areal proportion of filamentous algae* (XFC_ALG) and *percent pool* (PCT_POOL) had both similar least-impacted distributions across bioregions and consistent sensitivity by bioregions (see Appendix D, box plot labels start with either a H or L for moderately/highly and least-impacted). For *areal proportion of filamentous algae*, the only exception was the Bruneau River site (#77), and this site had relatively high nitrogen (136 μg/L) for a least-impacted site. For percent pool, notable exceptions were the least-impacted Bruneau River site which had no pool and the moderately/highly-impacted Owyhee River site (#32) which had 68% pool.

Metrics with high sensitivity were eliminated from consideration for a variety of reasons. Some metrics were not sensitive in all bioregions. These metrics were percent conifer canopy (PCAN_C; conifer not historically common along non-wadeable rivers in southern bioregion) and areal proportion of aquatic macrophytes (XFC_AQM; uncommon in Northern bioregion). Some metrics had the opposite relationship with impairment than that expected. These metrics were percent riparian ground layer barren (XGB) which decreased with impairment and areal proportion of overhanging vegetation which increased with impairment (XFC_OHV). Mean of bank full height (XBKF_H), not expected to be related to impairment, was eliminated from consideration based on differences in least-impacted distributions by bioregion. With relatively little agriculture in the Northern bioregion, agricultural disturbances in the riparian area (W1_HAG) was excluded in favor of a more general metric, all types of disturbances in the riparian area (W1_HALL).

Table 15: Sensitivity of water chemistry metrics to detect impairment.

Metric	Metric Sensitivity	Definition	Correlation with Conductivity
ALKCALC	3	Calculated Alkalinity (ueq/L)	0.99
ANC	3	Gran ANC (ueq/L)	0.99
ANSUM	3	Sum of Anions (ueq/L)	1.00
CA	3	Calcium (ueq/L)	0.94
CATSUM	3	Sum of Cations (ueq/L)	1.00
CL	3	Chloride (ueq/L)	0.96
CO3	3	Calculated Carbonate (ueq/L)	0.68
CONCAL	3	Calculated Conductivity (uS/cm)	1.00
COND	3	Conductivity (uS)	1.00
CONDHO	3	Debye-Huckel-Onsager Calc. Cond. (uS/cm)	1.00
DIC	3	Dissolved Inorganic Carbon (mg/L)	0.99
DOC	3	Dissolved Organic Carbon (mg/L)	0.53
HCO3	3	Calculated Bicarbonate (ueq/L)	0.99
IONSTR	3	Ionic Strength (M)	0.94
K	3	Potassium (ueq/L)	0.89
MG	3	Magnesium (ueq/L)	0.95
NA	3	Sodium (ueq/L)	0.94
NH4	3	Ammonium (ueq/L)	0.76
NO3	3	Nitrate (ueq/L)	0.59
NTL	3	Total Nitrogen (ug/L)	0.68
ORGION	3	Est. Organic Anion (ueq/L)	0.53
PTL	3	Total Phosphorus (ug/L)	0.19
PHSTVL	3	Closed Headspace pH	0.40
SE	3	Dissolved Selenium (ug/L)	0.67
SO4	3	Sulfate (ueq/L)	0.93
SOBC	3	Sum of Base Cations (ueq/L)	1.00
H	2	H+ from PHSTVL (ueq/L)	-0.24
OH	2	Hydroxide from PHSTVL (ueq/L)	0.07
SIO2	2	Silica (mg/L SiO2)	0.53
TURB	2	Turbidity (NTU)	0.29
COLOR	1	Color (PCU)	-0.01
TSS	1	Total Suspended Solids (mg/L)	0.55
ZN	1	Dissolved Zinc (ug/L)	-0.10

Table 16: Correlation matrix for metrics in final water chemistry multi-metric index.

	Conductivity	pH	Total Nitrogen	Total Phosphorus
Conductivity	1.00			
pH	0.19	1.00		
Total Nitrogen	0.68	0.29	1.00	
Total Phosphorus	0.40	0.22	0.66	1.00

Table 17: Sensitivity of physical habitat metrics to detect impairment.

Metric	Metric Sensitivity	Definition
PCAN_C	3	Riparian Canopy Coniferous (Fraction of reach)
PCT_POOL	3	Pools -- All Types (% of reach)
W1_HAG	3	Rip Dist--Sum Agric Types (Prox. Wt. Pres.)[a]
XBKF_H	3	Bankfull Height-Mean (m)
XFC_ALG	3	Littoral cover-filamentous. Algae (Areal Proportion)
XFC_AQM	3	Littoral cover-aquatic Macrophyte (Areal Proportion)
XFC_OHV	3	Littoral cover-overhang vegetation (Areal Proportion)
XGB	3	Riparian Ground Layer Barren (Cover)
LSUB_DMM	2	Thalweg substrate.-Mean Log10(Diameter Class mm)
PCT_SLOW	2	Slow Water Habitat (% Glide & Pool)
PCT_SNAG	2	Percent of reach with snags
V1TM100	2	LWD[b] volume in/above wetted channel(# / 100m-all sizes)
W1_HALL	2	Riparian Disturbance--Sum All Types (Prox. Wt. Pres.)[a]
XCL	2	Riparian Canopy > 0.3m DBH (Cover)
XFC_RCK	2	Littoral fish cover-boulders (Areal Proportion)
XLIT	2	Mean littoral depth (m)
XPCM	2	Riparian Canopy & MidLayer Present (Fraction of reach)
XPCMG	2	Riparian 3-Layers Present (Fraction of reach)
V1W_MSQ	1	LWD[b] volume in bankfull channel & dry(m^3/m^2-all sizes)
REACHLEN	1	Length of sample reach (m)
SDWXD	1	Stdev[c] of Width x Depth Product (m^2)
VLIT	1	Stdev[c] littoral depth (m)
W1_HNOAG	1	Riparian Disturbance--Sum Non-Ag Types (Prox. Wt. Pres.)[a]
W1H_WALL	1	Riparian Disturbance--Wall/Bank Revetment (Prox. Wt. Pres.)[a]
XC	1	Riparian Vegetation Canopy Cover
XFC_BRS	1	Littoral cover-brush & small debris (Areal Proportion)
XFC_LWD	1	Littoral cover-LWD[b] (Areal Proportion)
XG	1	Riparian Vegetation Ground Layer Cover
XPMG	1	Riparian mid & ground present (Fraction of reach)
XPMGH	1	Riparian mid & ground herb present (Fraction of reach)
XPMGW	1	Riparian mid & ground wood present (Fraction of reach)
PCT_BH	0	Thalweg substrate bedrock or hardpan -- >4 m (%)
PCT_FAST	0	Fast water habitat (% riffle & faster)
PCT_FN	0	Thalweg substrate Fines -- Silt/Clay/Muck (%)
PCT_SA	0	Thalweg substrate Sand -- .06-2 mm (%)
PCT_SAFN	0	Thalweg substrate Sand & Fines -- <2 mm (%)
PCT_SIDE	0	Side channel presence (% of reach)
SDDEPTH	0	Stdev[c] of Thalweg Depth (m)
SINU	0	Channel Sinuosity (m/m)
W1H_PIPE	0	Riparian Disturbance--Pipes influent/effluent (Prox. Wt. Pres.)[a]
XBKF_W	0	Bankfull Width--Mean (m)
XCDENBK	0	Mean Bank Canopy Density (%)
XCMGW	0	Riparian vegetation Canopy+Mid+Ground layer Woody Cover
XCMW	0	Riparian vegetation Canopy+Mid layer Woody Cover
XDEPTH	0	Thalweg Mean Depth (m)
XFC_ALL	0	Littoral cover-sum(all) (Areal Proportion)

Metric	Metric Sensitivity	Definition
XFC_BIG	0	Littoral cover –sum (LWD[b], Rock, Undercut Banks, Humis Areal Proportion)
XFC_HUM	0	Littoral cover -artificial structures (Areal Proportion)
XFC_NAT	0	Littoral cover -sum(natural types) (Areal Proportion)
XFC_UCB	0	Littoral cover -undercut banks (Areal Proportion)
XINC_H	0	Channel Incision height.-Mean (m)
XWD_RAT	0	Mean Width/Depth Ratio (m/m)
XWIDTH	0	Wetted Width -- Mean (m)
XWXD	0	Mean Width x Depth Product (m^2)

a-Proximity Weighted Pressures; b-Large Woody Debris; c-Standard Deviation

Of the ten metrics with medium sensitivity, *areal proportion of boulder* (XFC_RCK; 10" diameter or greater) had similar least-impacted distributions across bioregions and evidence of sensitivity in all bioregions. An exception was the Bruneau River site (#77) which had zero areal proportion of boulder. *Percent slow water* (PCT_SLOW) was omitted as redundant with the more sensitive percent pool. Other metrics were omitted for inconsistent sensitivity by bioregion (e.g., LSUB_DMM, PCT_SNAG, XLIT, V1TM100).

Physical habitat indices were developed from sets of metrics with moderate pairwise correlations (<0.75). The final water physical habitat index consisted of four metrics: *pools (% of reach, all types), littoral filamentous algae cover (areal proportion), riparian disturbance (proximity weighted pressure, sum all types),* and *littoral fish cover (areal proportion of boulders).* Pairwise correlations were relatively mild (Table 18), evidence that each metric was contributing unique information. Reference minimums for percent pool and proportion boulder were zero; values below zero are not possible, therefore score 1 was not applicable (Table 19). Possible values of the physical habitat index range from 8 to 20. Good condition ratings were assigned to sites with index scores greater than or equal to 18. Fair condition ratings were assigned to sites with index scores from 14 to 16. Poor condition ratings were assigned to sites with index scores less than or equal to 12.

Table 18: Correlation matrix for metrics in final physical habitat multi-metric index.

	Areal Proportion Boulder	Areal Proportion Fil. Algae	Percent Pool	Riparian Disturbance
Areal Proportion Boulder	1.00			
Areal Proportion Fil. Algae	-0.35	1.00		
Percent Pool	-0.03	-0.51	1.00	
Riparian Disturbance	-0.51	0.02	-0.35	1.00

Table 19 provides reference site percentiles for water chemistry and physical habitat metrics included in final multi-metric indices and metric scoring ranges for good (5), fair (3) and poor (1) condition.

Table 19: Reference site percentiles and scoring ranges for water chemistry and physical habitat metrics used in multi-metric indices.

		Percentile					Metric Score		
Metric	**Abbrev.**	**0**	**25**	**50**	**75**	**100**	**5**	**3**	**1**
pH[1]	PHSTVL	7.66	8.04	8.22	8.37	8.87	≤8.55	>8.55- 8.87	>8.87
Conductivity	COND	38.0	54.3	67.0	114.8	176.0	≤114.8	>114.8-176.0	>176.0
Total Nitrogen	NTL	38	60	90	114	145	≤114	>114-145	>145
Total Phosphorus	PTL	1	3	4	9	38	≤9	>9-38	>38
Riparian Disturbance	W1_HALL	0.00	0.59	0.88	1.94	3.94	≤1.94	>1.94-3.94	>3.94
Areal Proportion Fil. Algae	XFC_ALG	0.00	0.009	0.020	0.027	0.427	≤0.03	>0.03-0.43	>0.43
Areal Proportion Boulder[2]	XFC_RCK	0.00	0.078	0.165	0.280	0.498	≥0.08	0.00-<0.08	NA
Percent Pool[2]	PCT_POOL	0.0	5.2	20.4	27.8	98.0	≥5	0-<5	NA

[1] **Metric scoring based on the 87.5 percentile (8.55) and maximum. The pH minimum and 12.5th percentile for reference sites were not low enough to provide meaningful scoring bands to penalize low pH scores. None of the moderately or highly impacted sites had a pH value low enough to warrant a penalty. Future surveys may observe lower pH values, therefore, if the the index is used for future surveys, best professional judgment should be used to set scoring bands that penalize low pH.**

[2] **Reference minimum was zero. Values below zero are not possible, therefore score 1 was not applicable.**

Also a combined water chemistry and physical habitat index (WCPHI) consisting of all metrics in the water chemistry and physical habitat indices was calculated. Possible values of this index range from 12 to 40. Table 20 provides the index and condition rating for the river sites. To distinguish between site classifications assigned in the selection of reference sites process (i.e., least-impacted, moderately-impacted, highly-impacted) and multi-metric index estimates of condition, condition will be referred to as Good, Fair, or Poor. Good condition ratings were assigned to sites with index scores greater than or equal to 34. Fair condition ratings were assigned to sites with index scores between 22 and 34. Poor condition ratings were assigned to sites with index scores less than or equal to 22. The cut-offs for Good, Fair, and Poor condition ratings were chosen to maximize agreement with, respectively, the initial least-impacted, moderately-impacted, and highly-impacted classifications. Table 20 also includes condition ratings for the water chemistry index and for the physical habitat index.

The WCPHI improved discrimination over that based on the water chemistry index alone or the physical habitat index alone. For example, condition estimates using the combined index had 91% (40/44) agreement with site-impact classifications least/moderately/highly-impacted, but condition estimates with water chemistry index or the physical habitat index alone had 80% (35/44) and 77% (34/44) agreement with site-impact classifications. The eight metrics (4 physical habitat, 4 water chemistry) used in the WCPHI fall into three general metric types: general impairment, excess nutrients, and riparian disturbance. *Conductivity* and *pH* detect general impairment. *Areal proportion of filamentous algae*, *total phosphorus*, and *total nitrogen* detect excess nutrients. *Riparian disturbance, areal proportion boulder,* and *percent pool* detect disturbance to riparian area/stream channel.

Table 20: Water Chemistry and Physical Habitat Index for Idaho REMAP river sites (2002-2004).

Site ID	WCPHI	Condition Rating	Physical Habitat Index	Water Chemistry Index
1	**18**	Poor	12	6
4	**40**	Good	20	20
6	**38**	Good	18	20
7	**38**	Good	20	18
8	**34**	Good	16	16
9	**24**	Fair	16	8
11	**28**	Fair	16	12
12	**36**	Good	16	20
14	**38**	Good	20	18
15	**26**	Fair	16	10
18	**34**	Good	18	16
19	**34**	Good	18	16
22	**40**	Good	20	20
23	**30**	Fair	16	14
26	**16**	Poor	10	6
27	**38**	Good	18	20
28	**36**	Good	16	20
29	**20**	Poor	12	8
31	**32**	Fair	18	14
32	**26**	Fair	18	8
34	**34**	Good	18	16
35	**22**	Poor	16	6
37	**26**	Fair	16	10
38	**32**	Fair	18	14
39	**34**	Good	20	12
40	**38**	Good	18	18
42	**24**	Fair	14	10
44	**38**	Good	18	20
45	**26**	Fair	14	12
48	**32**	Fair	16	16
49	**40**	Good	20	20
50	**20**	Poor	12	8
52	**34**	Good	18	16
53	**36**	Good	16	20
55	**36**	Good	18	18
56	**38**	Good	18	20
70	**22**	Poor	12	10
77	**30**	Fair	14	16
79	**28**	Fair	16	12
92	**28**	Fair	16	12
103	**20**	Poor	12	8
115	**16**	Poor	12	4
130	**20**	Poor	10	10
131	**24**	Fair	14	10

Table 21: Correlation matrix for metrics in final water chemistry and physical habitat multi-metric index.

	Conductivity	pH	Total Nitrogen	Total Phosphorus	Areal Proportion Boulder	Areal Proportion Fil. Algae	Percent Pool	Riparian Disturbance
Conductivity	1.00							
pH	0.19	1.00						
Total Nitrogen	0.68	0.29	1.00					
Total Phosphorus	0.40	0.22	0.66	1.00				
Areal Proportion Boulder	-0.37	-0.35	-0.37	-0.25	1.00			
Areal Proportion Fil. Algae	0.43	0.39	0.43	0.28	-0.35	1.00		
Percent Pool	-0.35	-0.14	-0.27	-0.25	-0.03	-0.51	1.00	
Riparian Disturbance	0.43	0.04	0.38	0.32	-0.51	0.02	-0.35	1.00

C.5.3. Macroinvertebrates

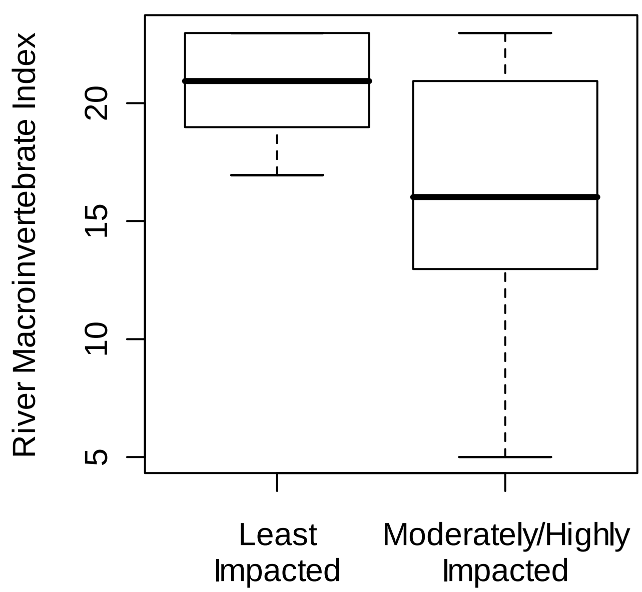
C.5.3.1. River Macroinvertebrate Index (RMI) condition ratings of REMAP sites

When the RMI was applied to the REMAP data it correctly classified all twenty-two least-impacted sites (100% sensitivity) but at the cost of classifying eleven of twenty-two a priori moderately/highly-impacted sites as least-impacted (50% specificity). The RMI rated thirty-three sites in Good, three in Fair, and eight in Poor condition (Table 24). The RMI discriminated poorly between sites with moderately and highly impacted final statuses based on water chemistry and best professional judgment. Overall agreement between condition ratings Good and Fair/Poor with least-impacted and moderately/highly-impacted final statuses was 75%. Agreement could not be improved by use of other ranges of the index to define condition.

The poor agreement between RMI condition rating and final status was due to reduced metric sensitivity at REMAP sites. For three out of five RMI metrics, sensitivity at REMAP sites was less than sensitivity at RMI sites. Metric sensitivity for RMI sites and for REMAP sites was 3 and 2 for TOTLRICH, 3 and 2 for PCTELMI, and 2 and 0 for DOM1PIND. In both studies, metric sensitivity was 3 for EPTRICH and 1 for PCTPRED. Lower sensitivity may be due to differences in survey protocols and quality of reference sites. It is also possible that RMI sensitivity estimates based on only five reference sites were overestimates. PCTPRED was expected to decrease with impairment, but three of the seven highest values were at moderately/highly-impacted sites (Sites 9, 35, 103, and 130). DOM1PIND was expected to increase with impairment, but seven of the ten lowest values were at moderately/highly-impacted sites (Sites 11, 23, 42, 8, 70, 79, and 103).

Boxplots for the RMI by least-impacted and moderately/highly-impacted groups had substantial overlap (Figure 17).

Figure 17: Boxplots for Idaho's River Macroinvertebrate Index by Least-Impacted and Moderately/Highly-Impacted REMAP sites.



High pairwise collinearity between RMI metrics in both the data used to develop the RMI (Table 22) and REMAP data (Table 23) may limit predictive performance at new sites. Prediction of impairment status at new sites using the RMI is, in statistical science, termed out-of-sample prediction. In regression, the precision of out-of-sample prediction decreases as collinearity in the covariates increases. This is sometimes referred to as the *picket fence dilemma* (Hocking et al. 1983). Prediction with a multi-metric index has the advantage of being simple to do, but the picket fence dilemma remains.

Table 22: Correlation matrix for RMI metrics calculated from data used to develop the RMI.

	DOM1PIND	EPT_RICH	PCTELMI	PCTPRED	TOTLRICH
DOM1PIND	1.00				
EPT_RICH	-0.59	1.00			
PCTELMI	-0.46	0.65	1.00		
PCTPRED	-0.22	0.51	0.36	1.00	
TOTLRICH[1]	-0.45	0.94	0.57	0.48	1.00

[1] There were missing values for TOTLRICH. Correlation was estimated for pairwise complete observations.

Table 23: Correlation matrix for RMI metrics calculated from REMAP data

	DOM1PIND	EPT_RICH	PCTELMI	PCTPRED	TOTLRICH
DOM1PIND	1.00				
EPT_RICH	-0.52	1.00			
PCTELMI	-0.32	0.18	1.00		
PCTPRED	-0.59	0.56	0.18	1.00	
TOTLRICH	-0.80	0.83	0.35	0.64	1.00

The RMI restricts scores for percent predator to be 1 or 3 (maximum RMI value = 23). A modification of the RMI that allowed the percent predator metric to take scores 1, 3, or 5 did not improve predictive performance (maximum index score = 25).

Metric sensitivity was assessed for all macroinvertebrate metrics. Three metrics had sensitivity 3, fourteen had sensitivity 2, five had sensitivity 1, and twelve has sensitivity 0. The most sensitive metrics were *number of ephemeroptera, plecoptera, and trichoptera taxa* (EPTRICH), *percent non-insect individuals* (NOINPIND), and *percent plecoptera individuals* (PLECPIND). All three showed evidence of both consistent sensitivity and similar least-impacted distribution across bioregions. Metric change with impairment was as expected: NOINPIND increased and PLECPIND and EPTRICH decreased with impairment.

Metrics that increase in value (DOM1PIND, DOM5PIND, NONINPIND) with impairment were scored 1 for site values greater than the maximum, 3 for site values greater than the 75th percentile but less than or equal to the maximum, and 5 for site values less than or equal to the 75th percentile. Metrics that decrease in value (EPTRICH, PCTELMI, PCTPRED, PLECPIND, PLECRICH, TOTLRICH) with impairment were scored 1 for site values less than the minimum, 3 for site values less than the 25th percentile but greater than or equal to the minimum, and 5 for site values greater than or equal to the 25th percentile.

Table 24: RMI condition ratings for REMAP sites. Final Status is the site-impact classification based on water chemistry and best professional judgment that sites were either least-impacted(L), moderately-impacted (M), or highly-impacted (H).

Site ID	Bioregion	River	24K Map	RMI	Condition Rating	Final Status	TOTLRICH	DOM1PIND	EPTRICH	PCTPRED	PCTELMI
1	Southern	ROCK CR	Twin Falls	7	Poor	H	17	85.4	4	0.0	0.4
4	Northern	CLEARWATER R,N FK	Clarke Mountain	17	Good	L	43	26.1	6	3.5	0.3
6	Central	BOISE R,S FK	Featherville	21	Good	L	47	21.4	17	5.5	5.7
7	Central	SALMON R	Cottontail Point	23	Good	L	60	18.0	18	8.4	5.0
8	Northern	ST JOE R	Saint Joe Baldy	19	Good	L	48	25.8	8	4.9	1.7
9	Southern	BLACKFOOT R	Blackfoot	13	Poor	M	47	36.8	9	4.5	0.0
11	Northern	CLEARWATER R,S FK	Stites	23	Good	M	71	11.3	28	7.7	6.0
12	Northern	PRIEST R	Prater Mountain	23	Good	L	73	17.5	22	7.5	3.0
14	Central	PAYETTE R	Banks	21	Good	L	51	26.5	15	12.3	3.5
15	Central	SALMON R	Ulysses Mountain	19	Good	M	51	23.6	12	5.5	1.0
18	Central	SALMON R	Sheep Hill	23	Good	L	54	23.1	22	5.6	5.6
19	Northern	CLEARWATER R	Sixmile Creek	19	Good	L	57	46.2	17	6.4	0.4
22	Central	BOISE R,S FK	Jumbo Mountain	21	Good	L	54	43.4	21	4.2	4.4
23	Central	LITTLE SALMON R	Riggins	23	Good	M	49	16.2	20	4.9	3.5
26	Southern	SNAKE R	Opalene Gulch	5	Poor	H	11	84.0	0	0.0	0.0
27	Northern	LOCHSA R	Greystone Butte	23	Good	L	67	34.6	29	7.5	2.9
28	Northern	COEUR D'ALENE R	Prichard	23	Good	L	59	32.6	27	7.0	7.2
29	Southern	SNAKE R	Firth	17	Good	M	54	24.3	13	2.7	0.0
31	Central	SALMON R	Bald Mountain	21	Good	L	52	32.8	23	3.8	0.2
32	Southern	OWYHEE R	Red Basin	19	Good	M	55	42.7	15	4.0	12.3
34	Central	SALMON R,M FK	Artillery Dome	23	Good	L	60	16.3	17	3.8	9.9
35	Northern	POTLACH R	Juliaetta	13	Poor	H	35	39.4	9	4.9	0.5
37	Southern	BEAR R	Alexander	7	Poor	H	24	72.7	8	0.4	0.0
38	Central	SALMON R	Obsidian	21	Good	M	58	35.7	23	8.0	8.2
39	Central	SALMON R	Slate Creek	21	Good	L	59	20.3	13	11.0	14.5
40	Northern	COEUR D'ALENE R	Grizzly Mountain	23	Good	L	65	26.4	34	5.2	5.6
42	Central	WEISER R	Goodrich	21	Good	M	66	12.2	16	3.2	16.2
44	Northern	COEUR D'ALENE R	Pond Peak	19	Good	L	45	51.1	24	3.7	6.3
45	Central	SNAKE R	Wheaton Mountain	15	Fair	M	49	37.2	12	6.3	0.0
48	Central	SNAKE R	Heise	21	Good	M	62	16.0	18	2.3	0.7
49	Northern	KELLY CR	Scurvy Mountain	21	Good	L	57	34.9	22	6.1	6.2
50	Southern	SNAKE R	Thousand Springs	5	Poor	H	10	89.5	0	0.0	0.0
52	Northern	SELWAY R	Lowell	21	Good	L	80	7.2	35	12.5	1.1
53	Northern	ST JOE R	Marble Creek	21	Good	L	70	13.2	32	3.6	1.3
55	Central	SALMON R	MacKay Bar	23	Good	L	64	14.5	25	6.3	8.7
56	Northern	CLEARWATER R	Kamiah	17	Good	L	45	64.0	17	1.9	0.5
70	Southern	PORTNEUF R	Pocatello South	19	Good	H	40	14.4	9	4.7	4.1
77	Southern	BRUNEAU R,W FK	Indian Hot Springs	17	Good	L	40	37.8	5	2.1	16.5
79	Southern	SALMON R	Challis	23	Good	M	55	14.7	22	14.1	2.4
92	Southern	SALMON R	Salmon	15	Fair	M	40	54.3	15	5.2	0.8
103	Southern	WEISER R	Weiser South	13	Poor	H	36	15.6	6	3.7	0.0
115	Southern	SNAKE R	Walters Butte	5	Poor	H	18	78.4	2	0.0	0.0
130	Southern	PORTNEUF R	Lava Hot Springs	19	Good	H	48	23.5	6	3.1	7.7
131	Southern	PAYETTE R	Northwest Emmett	15	Fair	M	46	30.3	9	2.8	0.0

C.5.3.2. Development of a Macroinvertebrate Index from REMAP metrics

Correlations with EPTRICH were -0.67 (NOINPIND) and 0.80 (PLECPIND). Correlation between NOINPIND and PLECPIND was -0.47.

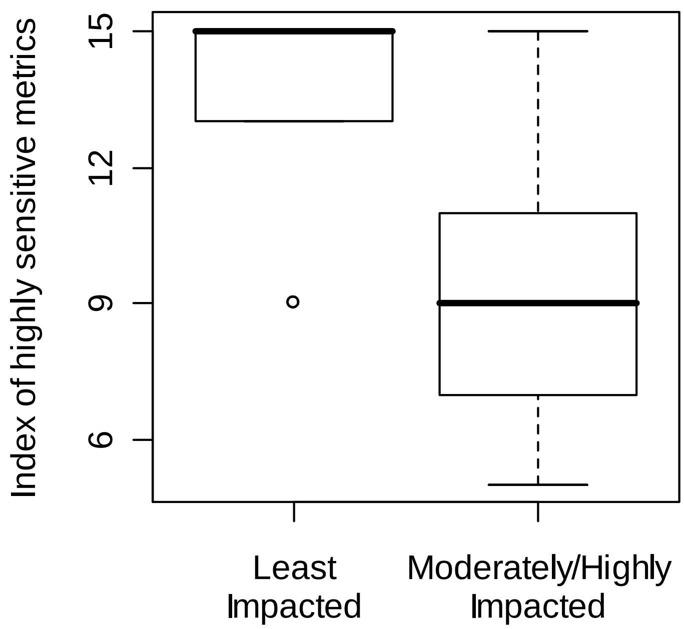
An index based on these three metrics performed better than the RMI. This index rated twenty-four sites in Good, seventeen in Fair, and four in Poor condition (Table 26). Like the RMI, discrimination between moderately and highly impacted sites was poor. This index correctly classified eighteen of twenty-two (82%) least-impacted sites and seventeen of twenty-two (77%) moderately/highly-impacted sites. Overall agreement between condition ratings Good and Fair/Poor with least-impacted and moderately/highly-impacted final statuses was 80% (35/44). Despite a sensitivity of 3, PLECPIND, expected to decrease with impairment, was 0 for five least-impacted sites (Sites 4, 8, 39, 56, and 77) which weakened discrimination.

Underlining the redundancy in metrics, 80% agreement was also achieved by rating sites with NOINPIND less than 18% as Good condition which correctly classifies nineteen of twenty-two (86%) least-impacted and sixteen of twenty-two (73%) moderately/highly-impacted sites.

The extent to which REMAP macroinvertebrate metrics were redundant for predicting least-impacted status was assessed using logistic regression. In stepwise model selection by Akaike Information Criterion [AIC] (Akaike 1974), the selected model included only the first principal component of all macroinvertebrate metrics (likelihood ratio χ^2=12.894, p=0.0003). The first principal component had a large contribution from species richness metrics.

The separation in boxplots in Figure 18 is misleading since the index was 9 for four least-impacted sites and 15 for three moderately/highly-impacted sites.

Figure 18: Boxplots for an index based on the three macroinvertebrate metrics with sensitivity 3 by Least-Impacted and Moderately/Highly-Impacted REMAP sites.



Another index (not tabled) based on metrics in the main effects regression model that minimized AIC (NOINPIND and number of plecoptera taxa (PLECRICH)) also performed better than the RMI. This index correctly classified fifteen of twenty-two (68%) least-impacted sites and nineteen of twenty-two (86%) moderately/highly-impacted sites. Overall agreement between condition ratings Good and Fair/Poor with least-impacted and moderately/highly-impacted final statuses was 77% (34/44). PLECRICH is expected to decrease with impairment, but five sites with least-impacted final status had 0 PLECRICH. Correlation between NOINPIND and PLECRICH was -0.50.

Metrics scoring rules for metrics included in reported indices are provided in Table 25. Other attempts to improve upon these indices were not successful.

Table 25: Reference site percentiles and scoring ranges for macroinvertebrate metrics used in multi-metric indices.

		Percentile					Metric Score		
Metric	**Abbreviation**	**0**	**25**	**50**	**75**	**100**	**5**	**3**	**1**
Number of EPT Taxa	EPTRICH	5	17	22	25	35	≥17	≥5, <17	<5
Number of Plecoptera Taxa1	PLECRICH	0	1	3	4	6	≥1	0	NA
Number of Taxa	TOTLRICH	40	49	57	63	80	≥49	≥40, <49	<40
Percent Dominant Taxon	DOM1PIND	7.2	18.6	26.2	34.8	64.0	≤34.8	>34.8, ≤64.0	>64.0
Percent Elmidae Individuals	PCTELMI	0.2	1.4	4.7	6.3	16.5	≥1.4	≥0.2, <1.4	<0.2
Percent Non-Insect Individuals	NOINPIND	1.7	6.0	12.1	18.8	57.3	≤18.8	>18.8, ≤57.3	>57.3
Percent Plecoptera Individuals1	PLECPIND	0.0	0.2	0.7	1.3	2.7	≥0.2	≥0.0, <0.2	NA
Percent Predators Individuals	PCTPRED	1.9	3.8	5.5	6.3	16.5	≥16.5	≥6.3, <16.5	<6.3

[1] **Reference minimum was zero. Values below zero are not possible, therefore score 1 is not applicable**.

C.5.3.3. Summary

Given the current set of macroinvertebrate metrics available (in both RMI and REMAP studies), the predictive performance at new sites using either a multi-metric index or a regression model is limited by the redundancy of metrics. The RMI ratings were in poor agreement with final statuses at REMAP sites, and the RMI was very poorly calibrated (75% of sites rated Good). Metrics found to be sensitive in the RMI study tended to be less sensitive in this study. The index based on the three most sensitive metrics was in greater agreement with final status and was better calibrated, but this within-sample performance should be viewed as a best-case performance. Both indices included redundant metrics, and this may plague prediction at new sites. At this time, no macroinvertebrate index can be recommended as reliable for prediction at new sites. The larger sample size relative to the RMI study and use of an EMAP probability design are expected to provide more robust results, but the usefulness of the index based on the three most sensitive metrics, the simple rule that sites with low percent non-insect individuals are in Good condition, or other indices/rules to be developed from the Idaho REMAP survey data will be determined by predictive performance at new sites.

Table 26: Condition ratings for REMAP sites from an index based on the macroinvertebrate metrics with sensitive score 3 (highest sensitivity). Final Status is the site-impact classification based on water chemistry and best professional judgment that sites were either least-impacted(L), moderately-impacted (M), or highly-impacted (H).

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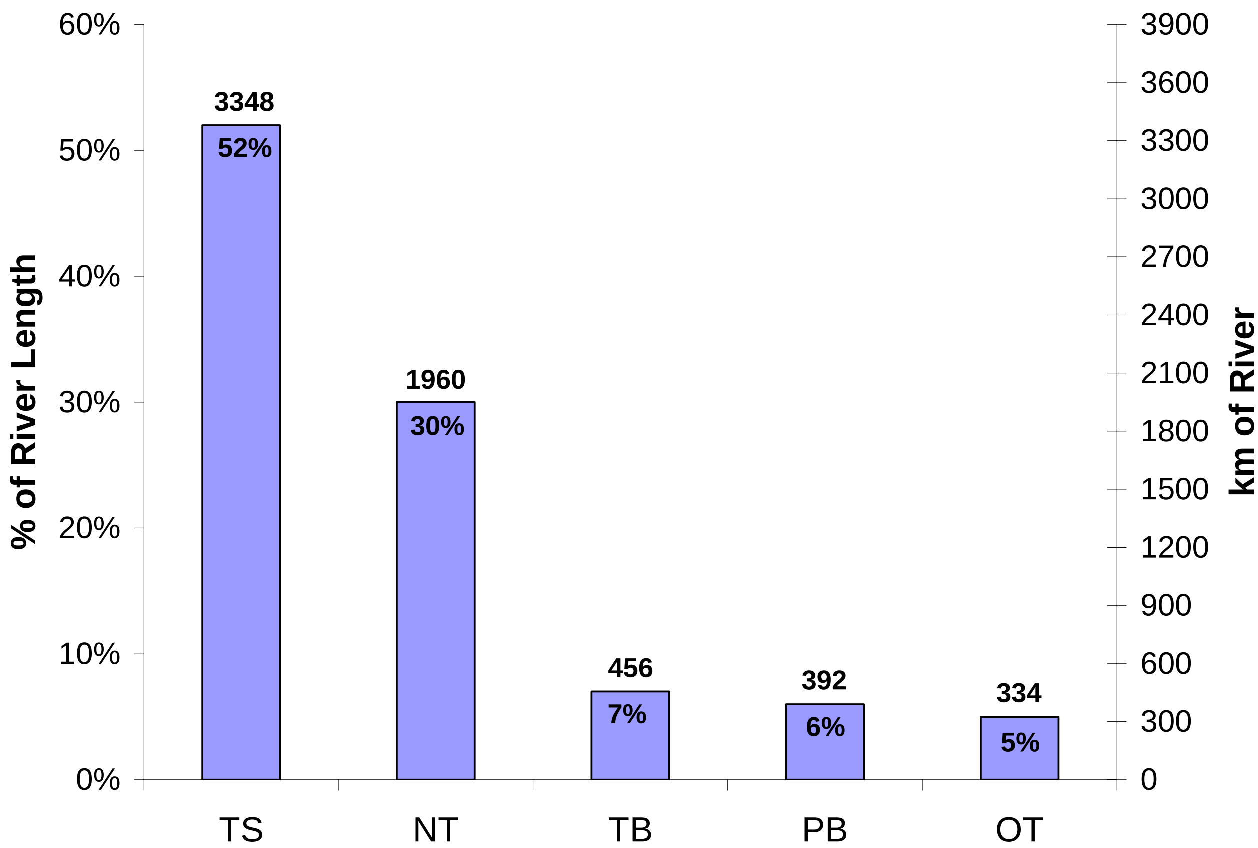
Site ID	Bioregion	River	24K Map	Index	Condition Rating	Final Status	EPTRICH	NOINPIND	PLECPIND
1	Southern	ROCK CR	Twin Falls	5	Poor	H	4	96.7	0.0
4	Northern	CLEARWATER R,N FK	Clarke Mountain	9	Fair	L	6	22.3	0.0
6	Central	BOISE R,S FK	Featherville	15	Good	L	17	12.0	0.5
7	Central	SALMON R	Cottontail Point	13	Good	L	18	19.2	0.4
8	Northern	ST JOE R	Saint Joe Baldy	9	Fair	L	8	36.8	0.0
9	Southern	BLACKFOOT R	Blackfoot	11	Fair	M	9	6.5	0.0
11	Northern	CLEARWATER R,S FK	Stites	15	Good	M	28	18.7	1.8
12	Northern	PRIEST R	Prater Mountain	15	Good	L	22	17.6	1.4
14	Central	PAYETTE R	Banks	13	Good	L	15	5.3	0.2
15	Central	SALMON R	Ulysses Mountain	9	Fair	M	12	41.6	0.0
18	Central	SALMON R	Sheep Hill	15	Good	L	22	14.4	0.4
19	Northern	CLEARWATER R	Sixmile Creek	15	Good	L	17	12.2	0.4
22	Central	BOISE R,S FK	Jumbo Mountain	15	Good	L	21	9.8	1.1
23	Central	LITTLE SALMON R	Riggins	15	Good	M	20	18.3	1.1
26	Southern	SNAKE R	Opalene Gulch	5	Poor	H	0	99.3	0.0
27	Northern	LOCHSA R	Greystone Butte	15	Good	L	29	4.1	2.7
28	Northern	COEUR D'ALENE R	Prichard	15	Good	L	27	7.1	1.3
29	Southern	SNAKE R	Firth	7	Fair	M	13	60.2	0.0
31	Central	SALMON R	Bald Mountain	15	Good	L	23	8.1	2.5
32	Southern	OWYHEE R	Red Basin	9	Fair	M	15	24.8	0.0
34	Central	SALMON R,M FK	Artillery Dome	13	Good	L	17	36.5	1.3
35	Northern	POTLACH R	Juliaetta	9	Fair	H	9	19.0	0.0
37	Southern	BEAR R	Alexander	11	Fair	H	8	8.6	0.0
38	Central	SALMON R	Obsidian	15	Good	M	23	6.4	0.5
39	Central	SALMON R	Slate Creek	9	Fair	L	13	57.3	0.0
40	Northern	COEUR D'ALENE R	Grizzly Mountain	15	Good	L	34	4.8	2.4
42	Central	WEISER R	Goodrich	11	Fair	M	16	32.1	0.2
44	Northern	COEUR D'ALENE R	Pond Peak	15	Good	L	24	1.7	1.3
45	Central	SNAKE R	Wheaton Mountain	7	Fair	M	12	63.1	0.2
48	Central	SNAKE R	Heise	13	Good	M	18	34.8	0.7
49	Northern	KELLY CR	Scurvy Mountain	15	Good	L	22	6.7	0.9
50	Southern	SNAKE R	Thousand Springs	5	Poor	H	0	97.9	0.0
52	Northern	SELWAY R	Lowell	15	Good	L	35	5.1	2.2
53	Northern	ST JOE R	Marble Creek	15	Good	L	32	13.0	1.1
55	Central	SALMON R	MacKay Bar	13	Good	L	25	16.6	0.2
56	Northern	CLEARWATER R	Kamiah	13	Good	L	17	5.7	0.0
70	Southern	PORTNEUF R	Pocatello South	9	Fair	H	9	43.6	0.0
77	Southern	BRUNEAU R,W FK	Indian Hot Springs	9	Fair	L	5	22.1	0.0
79	Southern	SALMON R	Challis	13	Good	M	22	20.4	0.6
92	Southern	SALMON R	Salmon	9	Fair	M	15	57.1	0.0
103	Southern	WEISER R	Weiser South	9	Fair	H	6	21.1	0.0
115	Southern	SNAKE R	Walters Butte	5	Poor	H	2	97.3	0.0
130	Southern	PORTNEUF R	Lava Hot Springs	9	Fair	H	6	34.2	0.0
131	Southern	PAYETTE R	Northwest Emmett	9	Fair	M	9	39.3	0.0

C.5.4. Estimates of Condition

C.5.4.1. Extent

The sample frame for this study includes all 5th order and greater streams in the NHD coverage. Once the sample draw was performed the sample sites were evaluated for target/non-target status. Those sites that did not adhere to the water body size criteria as non-wadeable waters (chiefly the Big Lost River) were determined to be non-target. Figure 19 details the percentage of the target population that was sampled target sites, those that were permanently inaccessible and those that were temporarily inaccessible. Reasons why a site may have been permanently inaccessible include physical barriers such as canyons or ravines that did not allow site access, or a site that fell in an unsafe area of the river system. Temporarily inaccessible sites are those where a landowner denied access, there was a fire blocking access to all reasonable points of entry, or low water prevented the use of non-wadeable protocols. In all, 52% (~3348 km) of the population was sampled with 6% (~392 km) of the population being permanently inaccessible and 7% (~456 km) being temporarily inaccessible. Non-target sites are those that did not fit the River category of the Waterbody Size Criteria and may include map error sites (where the x-site did not fall on a waterbody, the waterbody was a stream or a reservoir). Non-Target Sites accounted for 30% (1960 km) of the overall population.

Figure 19: Kilometers of rivers in key categories in Idaho, including Target Sampled (TS), Non-Target (NT), Temporarily Inaccessible (TB), Permanently Inaccessible (PB) and Target not sampled(OT).

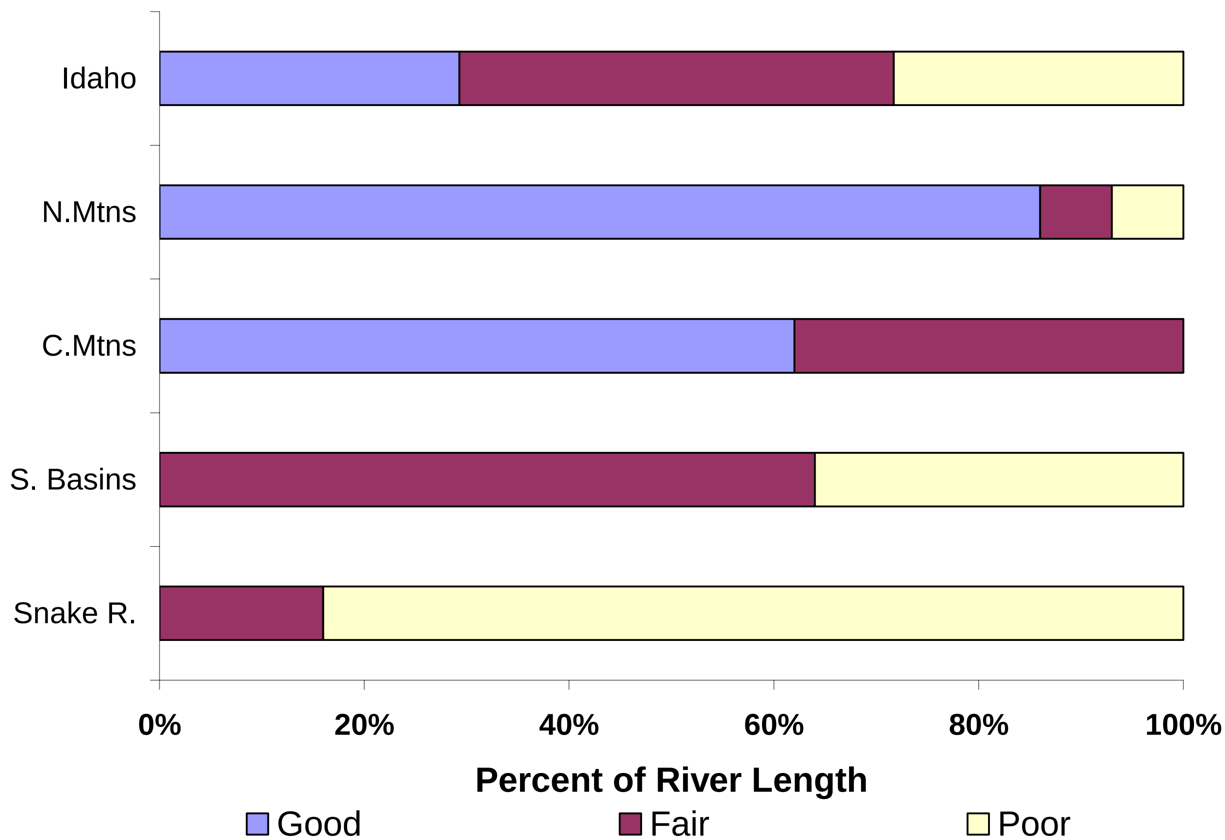


C.5.4.2. Chemical and Physical Condition

The WCPHI used to evaluate the site condition were ranked as good, fair and poor. In the previous section on index development each parameter used in the index development was given a score of 1, 3 or 5 depending upon its relation to the distribution of least-impacted site scores. Those values of 1, 3 and 5 were then used to create the condition ratings where 1 equates to a poor condition rating, 3 to fair and 5 to good.

Figure 20 shows extent of physical habitat condition ratings for each bioregion. For physical habitat all parameters were in either good or fair condition based upon the selected least-impacted river sites for both the northern mountain and the central Idaho bioregion. In the southern basins bioregion *riparian disturbance* and *algal growth* both had a small percentage of river length that was in poor condition. Overall the physical habitat of the river systems is in either good (values ranging 20-93%) or fair (values ranging 29-80%) condition.

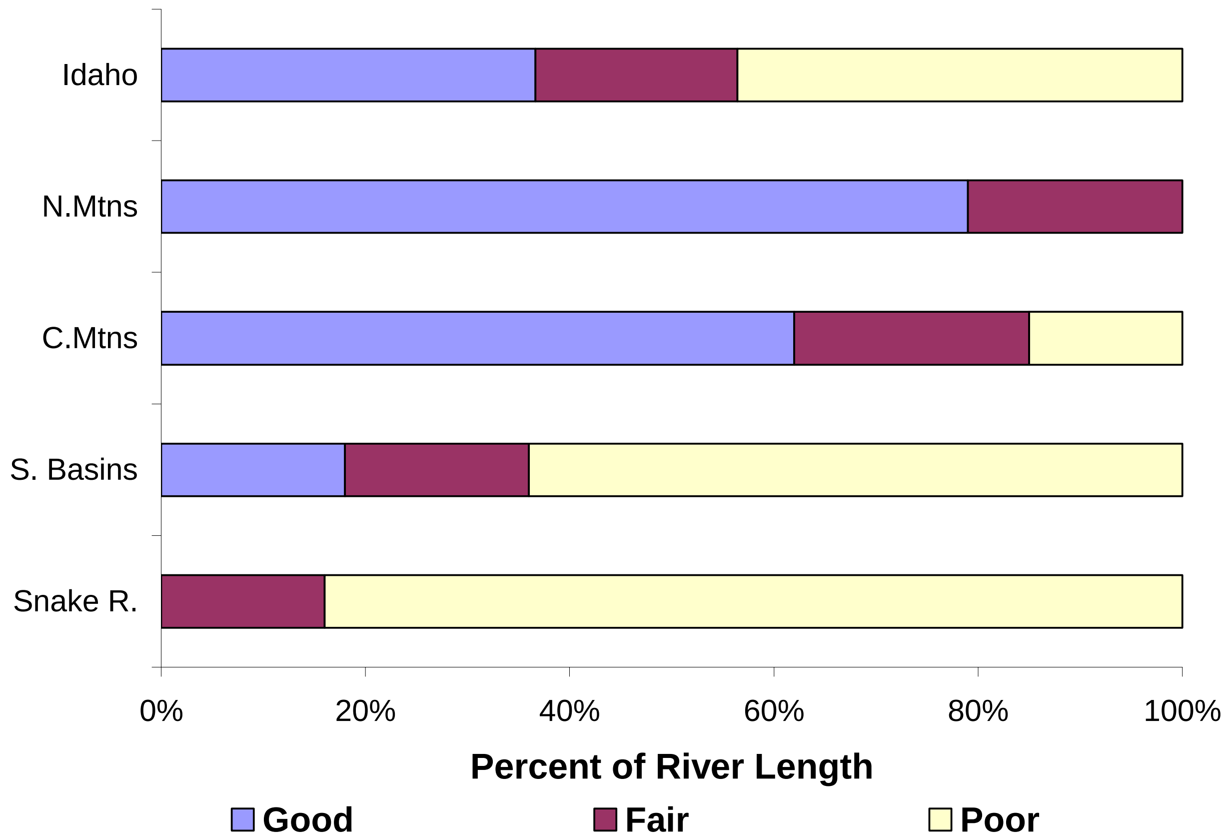
Figure 20: Water Chemistry and Physical Habitat Index estimates of Idaho river condition. Central Mountains and Southern Basins estimates exclude the Snake River.



Chemical and physical condition was also estimated using the geographic information system index (GISI) described in previous sections. Figure 21 displays the GISI estimates of Good, Fair, and Poor condition statewide and by bioregion. Statewide, 37% (2389 km) of river length was estimated to be in Good condition, 20% (1274 km) in Fair condition, and 44% (2827 km) in Poor condition. Both the GISI and WCPHI rated condition in southern Idaho as generally fair or poor and in central and northern Idaho as generally good.

The GIS index is largely redundant for chemical + physical condition, and therefore adds little unique information to the condition estimate. Because this index is redundant, it has potential to be an effective, low-cost tool for identifying areas of concern for future surveys.

Figure 21: GIS Index estimates of Idaho river condition. Central Mountains and Southern Basins estimates exclude the Snake River.



C.5.4.3. Macroinvertebrate Condition

Macroinvertebrate communities are studied as a measure of the overall cumulative impacts of water quality. They are relatively stationary and have lifespans that can take into account the various impacts of both short term and long term effects of changes in water quality. Condition ratings shown here were assigned based upon the macroinvertebrate index developed for this study and outlined in the previous section. This macroinvertebrate index was shown to have a higher sensitivity and classification efficiency than the RMI (which includes *number of EPT taxa*, *percent elmidae, percent predator, number of plecoptera taxa*, and *percent of individuals in the top five taxa*). The different condition class ratings were assigned as Poor for those sites scoring less than 9, Fair for those sites scoring between 9 and 19, and Good for sites scoring about 19.

Figure 22: Macroinvertebrate condition ratings.

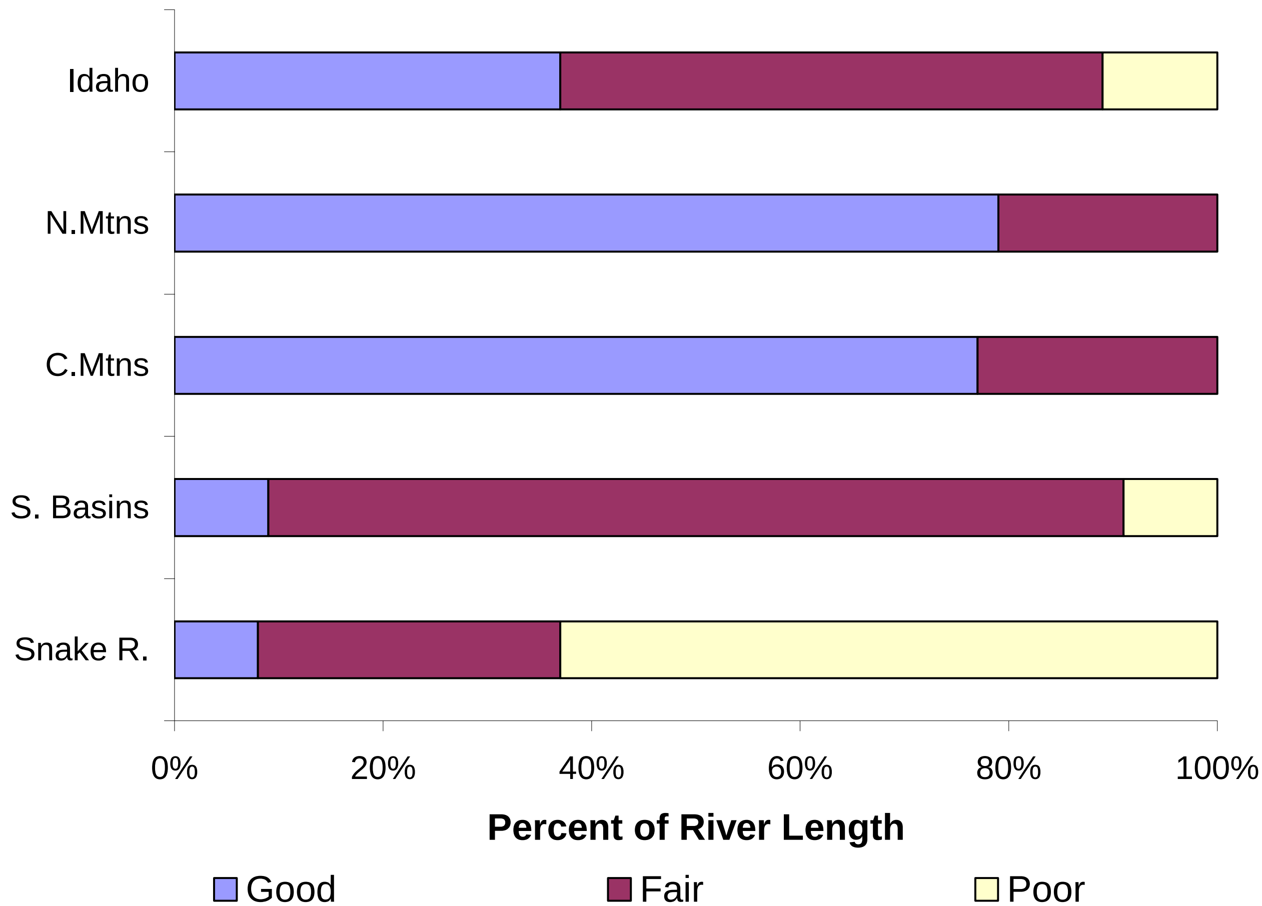


Figure 22 shows how the macroinvertebrate condition ratings are broken down across the state. Statewide, 37% (2380 km) of river length was estimated to be in Good condition, 52% (3366 km) in Fair condition, and 11% (745 km) in Poor condition. Similar to WCHPI and GISI estimates, condition was relatively poor in southern Idaho. Looking at a breakdown of the macroinvertebrate condition by bioregion shows that the rivers in the southern bioregion are the source of the poor condition ratings for macroinvertebrates in the state. 9% of the river length in the southern basins is in poor condition for macroinvertebrate scoring. The northern mountain region has the highest percent of river length in the good category (79%) with Central Idaho slightly lower at 77%.

C.5.4.4. Overall Estimate of Condition

To provide a single tool for assessing river condition, overall condition of rivers was estimated by combining condition ratings from the physical habitat/chemical and macroinvertebrate indices.

Overall condition was considered Good if chemical/physical and macroinvertebrate conditions were both Good. Overall condition was considered Fair if both individual conditions were Fair, if one was Good and the other was Poor, or if one was Fair and the other Good. Overall condition was considered Poor if both individual conditions were Poor or if one was Poor and the other was Fair.

This method of estimating overall condition is an adaptation of an existing Idaho method to integrate indices to assess ecosystem health (Grafe, C. S. 2002). No minimum/maximum thresholds for individual indices were used. Idaho uses minimum thresholds to protect against loss of information due to combining/averaging individual index ratings. Minimum and maximum thresholds can be used to make estimates of overall condition more sensitive to individual indices or individual metrics.

Figure 23 and Table 27 display the estimates of Good, Fair, and Poor overall condition of river statewide and by bioregion. Statewide, 25% (1623 km) of river length was estimated to be in Good overall condition, 47% (3026 km) in Fair overall condition, and 28% (1841 km) Poor overall condition. Overall condition was generally Fair or Poor in southern Idaho and Good in central and northern Idaho. On a percentage basis, river in Good overall condition ranged from 16% for the Snake River to 71% for the Northern bioregion; river in Poor overall condition ranged from 0% for the Central bioregion to 84% for the Snake River.

Figure 23: Overall estimates of river condition in Idaho.

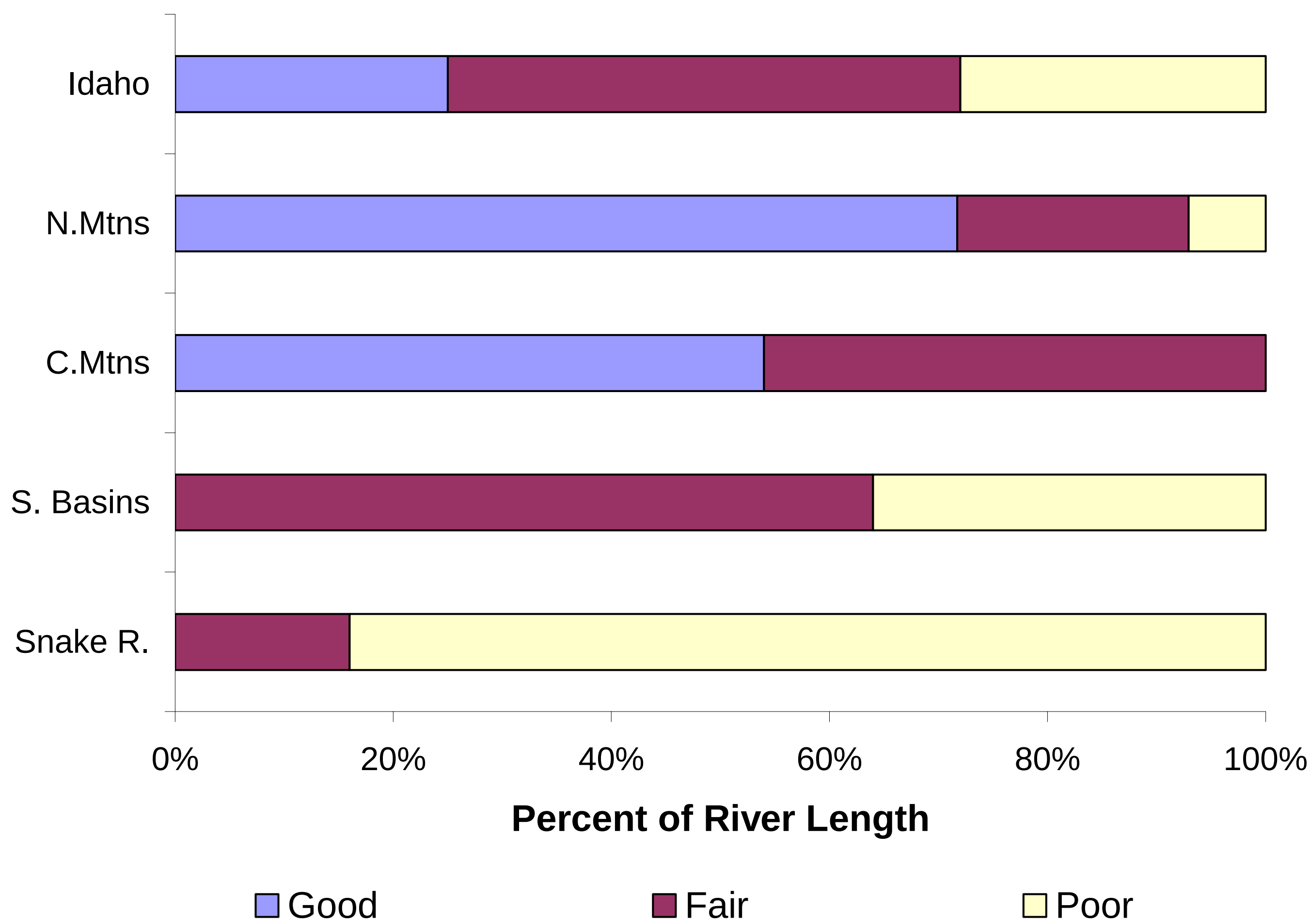


Table 27: Kilometers (percentages) of river in the target population in each condition category.

Area		Condition	
	Good	Fair	Poor
Idaho			
%	25	47	28
% (95% CI)	(17,33)	(32,62)	(15,42)
km	1623	3026	1841
km (95% CI)	(1164, 2083)	(1914, 4139)	(949, 2733)
Northern Mountains			
%	71	21	7
% (95% CI)	(50, 93)	(1, 42)	(0, 19)
km	866	260	87
km (95% CI)	(601, 1130)	(13, 506)	(0, 225)
Central Mountains			
%	54	46	0
% (95% CI)	(29, 79)	(21, 71)	NA
km	758	650	0
km (95% CI)	(404, 1111)	(296, 1103)	NA
Southern Basins			
%	0	64	36
% (95% CI)	NA	(38, 90)	(10, 62)
km	0	1998	1142
km (95% CI)	NA	(1180, 2816)	(324, 1960)
Snake River			
%	0	16	84
% (95% CI)	NA	(0, 35)	(65, 100)
km	0	119	613
km (95% CI)	NA	(9, 230)	(329, 898)

C.6. Conclusions

Overall 6,490 kilometers were determined to be in the target population. Of those in the target population ~13% were not sampled due to either temporary or permanent barriers. Sites that fell on the Snake River were deemed to be out of sample sites since the monitoring methods were not developed for great rivers such as the Snake.

GIS is partially effective for determining least-impacted status. Of the models considered, the cluster solution with the greatest agreement with site impact status based on water chemistry and expert judgment was from a subset of five metrics: *developed open space (%), pasture/hay area (%), cultivated crops area (%), dam storage capacity density*, and *dam storage area (%).* This solution had only five classifications in disagreement with expert judgment. The Clearwater River near Kamiah (#56) and the Salmon River near Bald Mountain (#31) sites were classified as moderately-impacted instead of least-impacted. One cluster had three sites each of which had a different site impact status based on water chemistry and expert judgment (Clearwater River near Six Mile Creek, #19; Snake River near Firth, #29; Potlach River near Juliaetta, #35).

Development of indices for physical habitat and chemistry showed that the metrics most sensitive and effective at detecting difference between high, moderate and low impact sites were *pools* (All Types % of reach), *littoral cover-filamentous algae* (areal proportion), *riparian disturbance* (Sum All Types, Prox. Wt. Pres.), *littoral fish cover-boulders* (areal proportion), *pH, conductivity, total phosphorus* and *total nitrogen*. A Water Chemistry and Physical Habitat Index was developed for this study and includes the metrics listed above. This WCPHI should good sensitivity to impairment with 91% (40/44) agreement with site-impact classifications based upon water chemistry and expert judgment cluster analysis. The eight metrics (4 physical habitat, 4 water chemistry) used in the WCPHI fall into three general metric types: general impairment, excess nutrients, and riparian disturbance. *Conductivity* and *pH* detect general impairment. *Areal proportion of filamentous algae*, *total phosphorus*, and *total nitrogen* detect excess nutrients. *Riparian disturbance, areal proportion boulder,* and *percent pool* detect disturbance to riparian area/stream channel.

Overall, the physical habitat/chemical index showed that statewide 37% (2389 km) of river length was estimated to be in Good condition, 20% (1274 km) in Fair condition, and 44% (2827 km) in Poor condition. Both the GISI and WCPHI rated condition in southern Idaho as generally fair or poor and in central and northern Idaho as generally good.

The current River Macroinvertebrate Index (RMI) is good at predicting status for that set of sites used in the development of the index, but suffers from overfit issues (picket fence) when using data from sites outside that dataset. A macroinvertebrate index using *number of EPT taxa, percent elmidae, percent predator, number of plecoptera taxa,* and *percent of individuals in the top 5 taxa* was recommended as being better able to differentiate between high, moderate and least impacted sites. Using the recommended index macroinvertebrate condition ratings across the state were 37% (2380 km) of river length was estimated to be in Good condition, 52% (3366 km) in Fair condition, and 11% (745 km) in Poor condition.

Statewide, 25% (1623 km) of river length was estimated to be in Good overall condition, 47% (3026 km) in Fair overall condition, and 28% (1841 km) Poor overall condition. Overall condition was generally Fair or Poor in southern Idaho and Good in central and northern Idaho. On a percentage basis, river in Good overall condition ranged from 16% for the Snake River to

71% for the Northern bioregion; river in Poor overall condition ranged from 0% for the Central bioregion to 84% for the Snake River.

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E. Appendices

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A. Graphic comparison of condition based on chemical and physical (habitat) indicators

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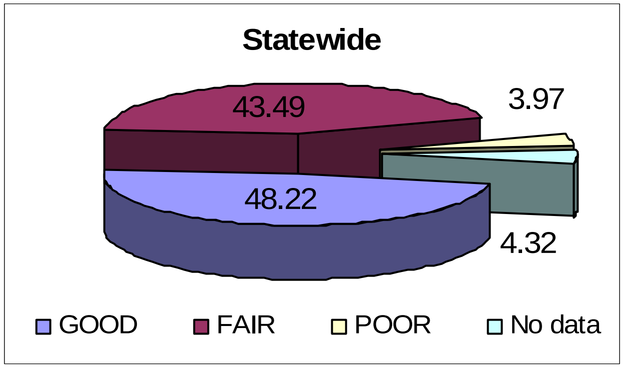
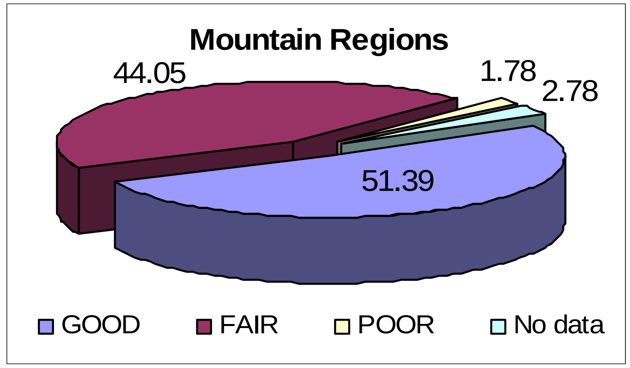
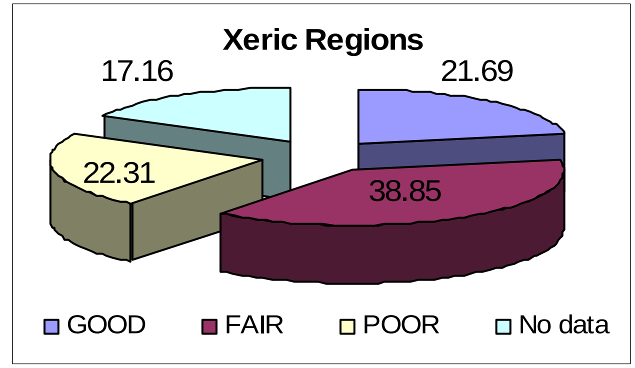
pH







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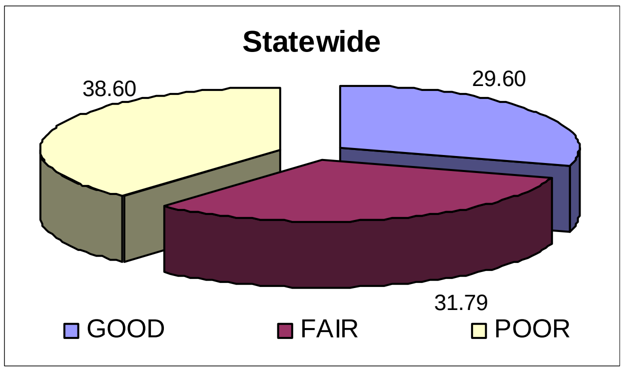

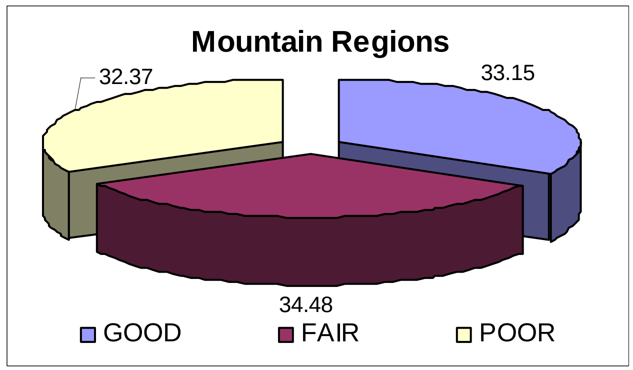

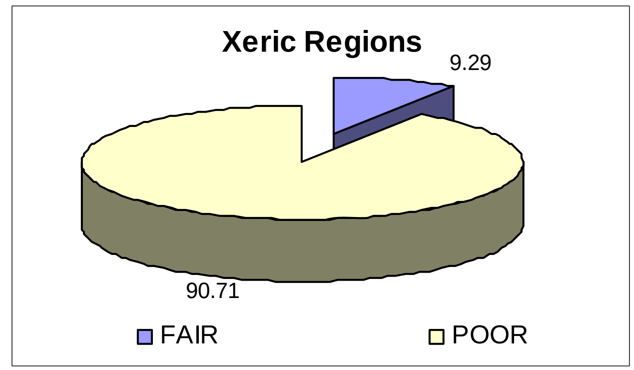

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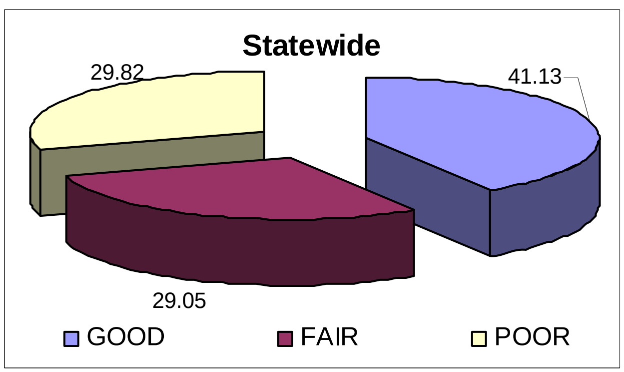

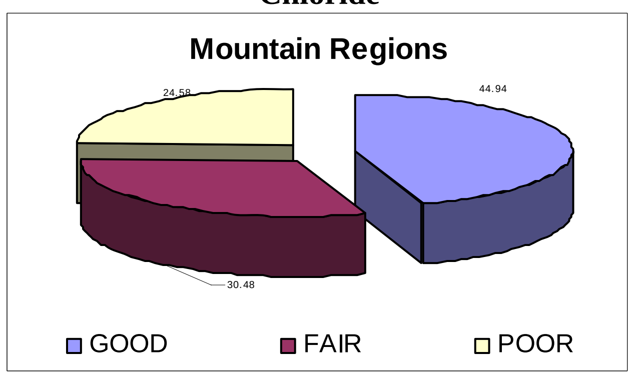

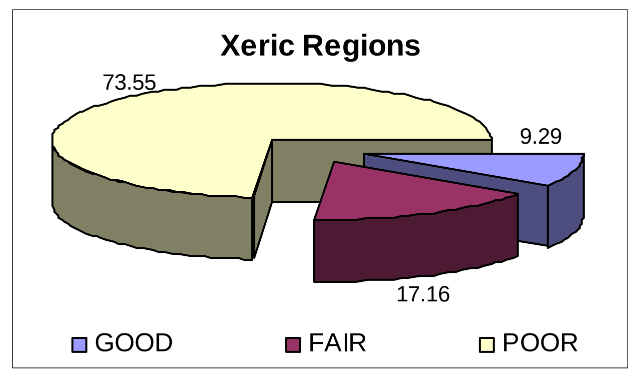

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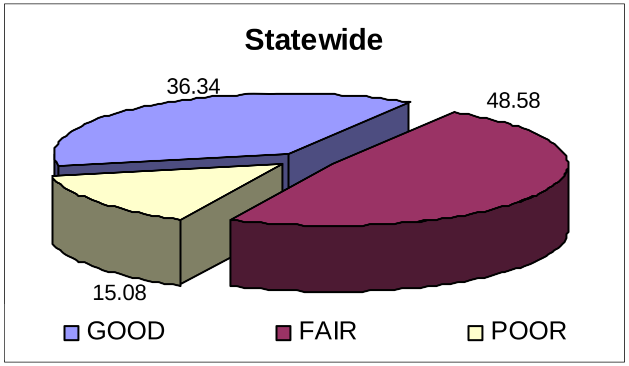
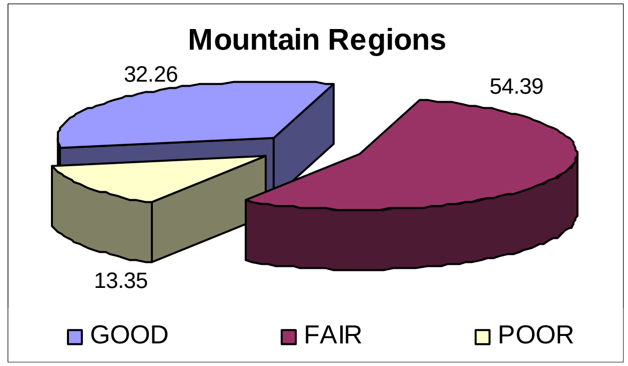
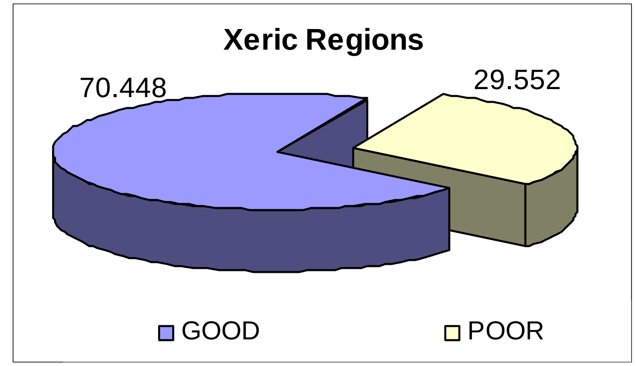
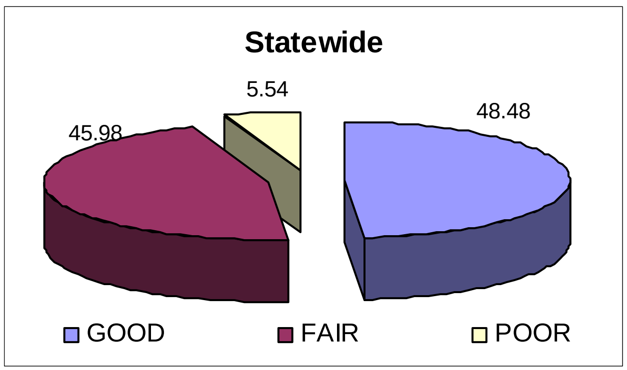
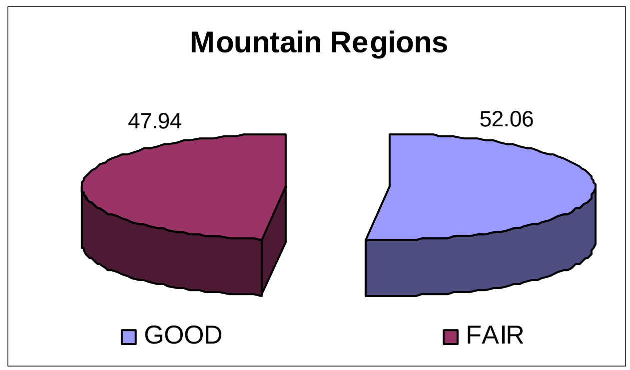


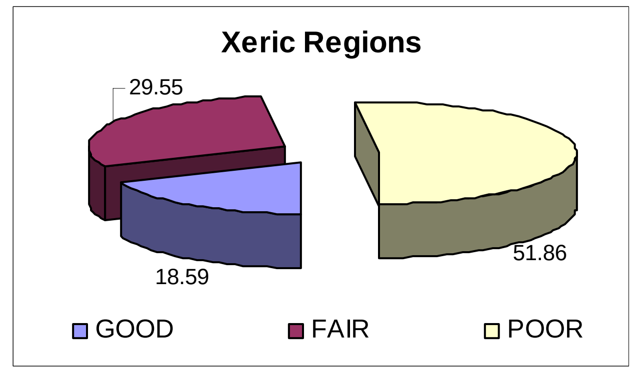




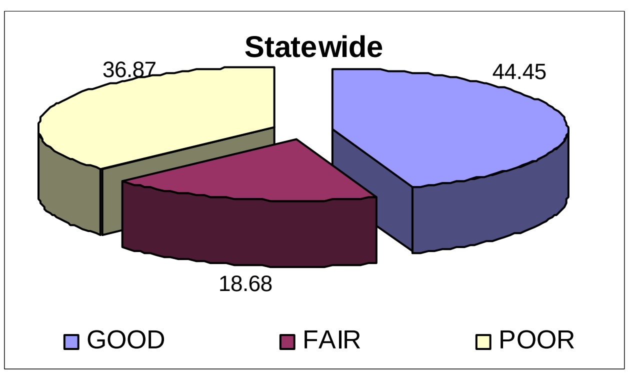
Total Nitrogen

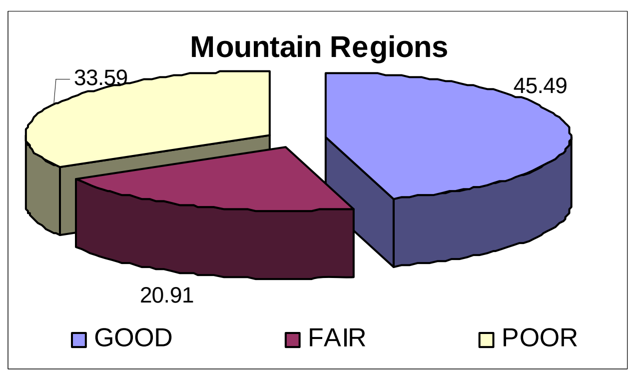


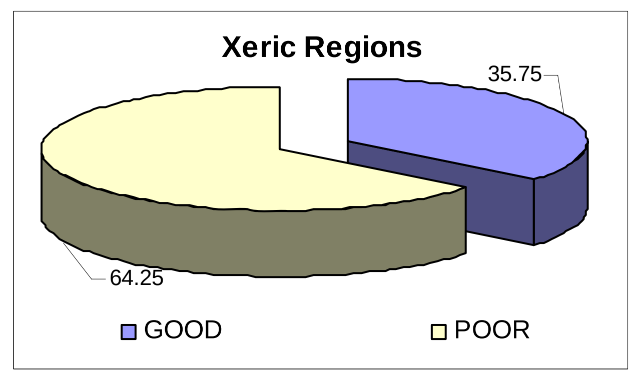




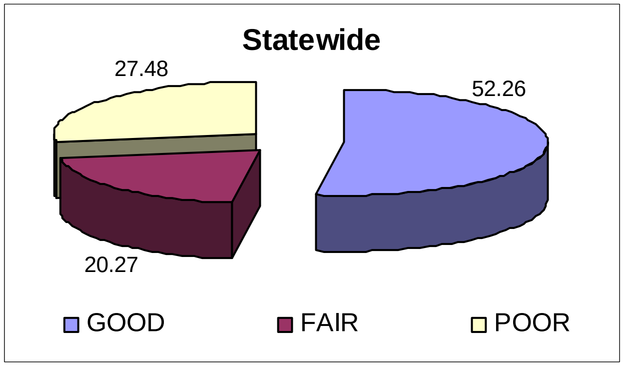
Total Phosphorus

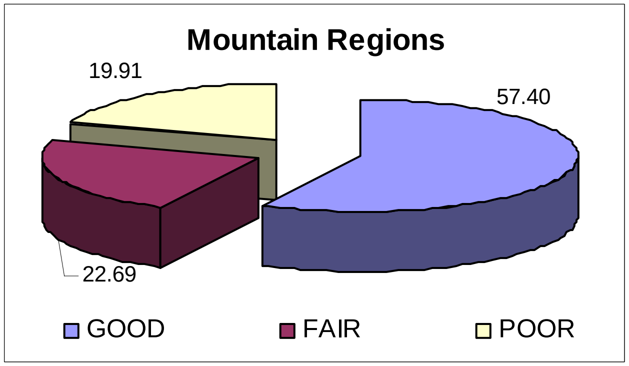


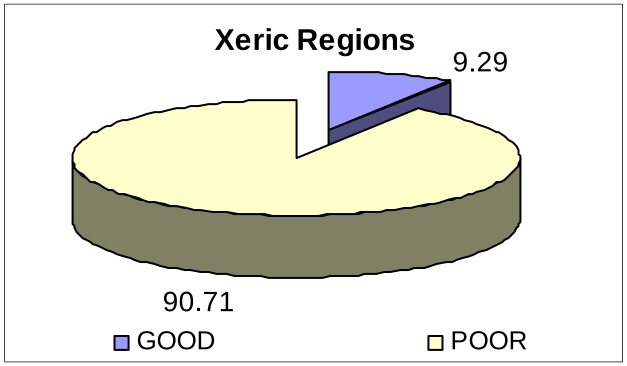




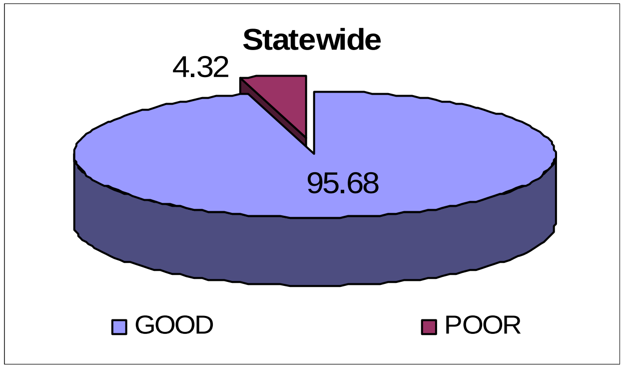
Conductivity

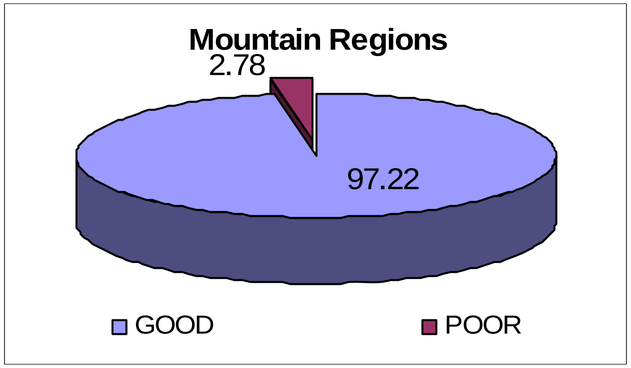


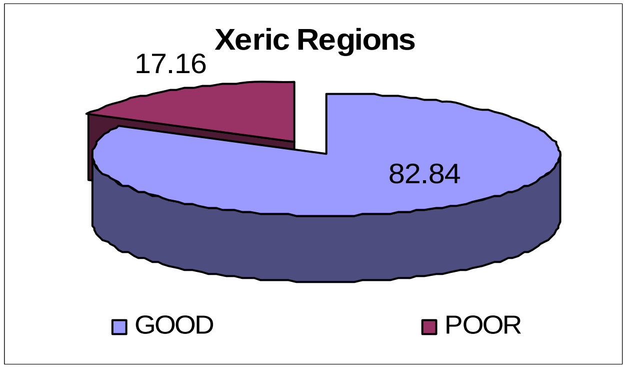




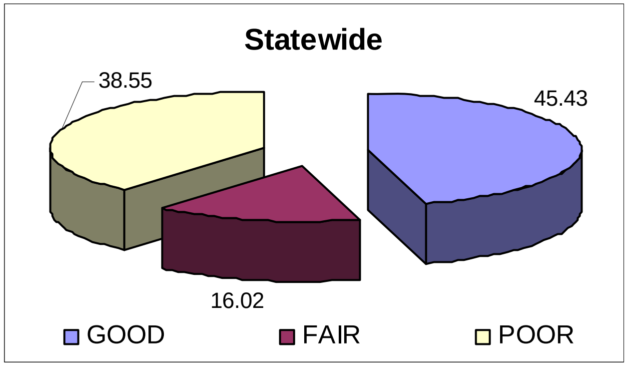
Dissolved Oxygen

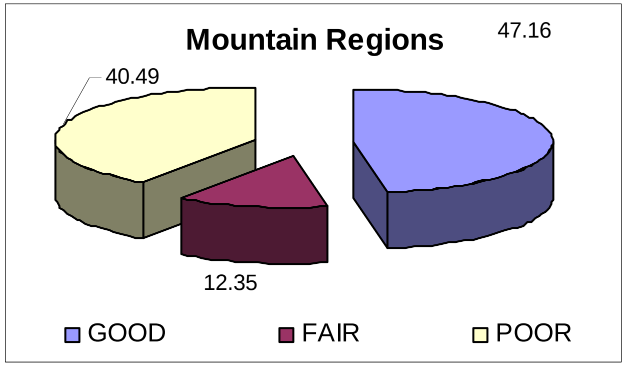


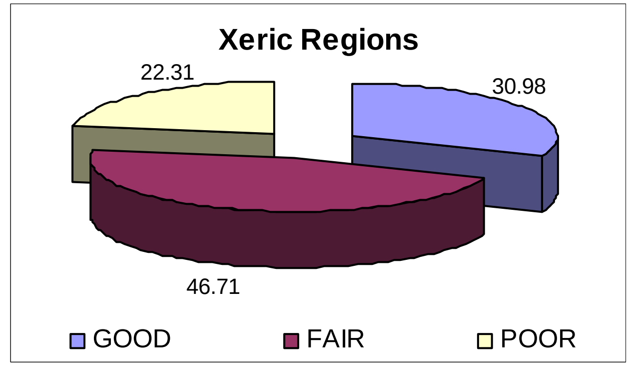




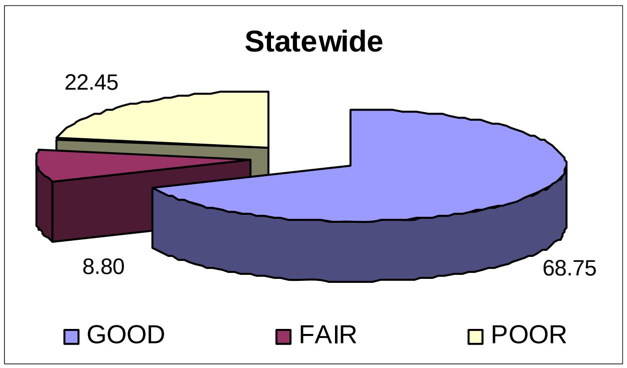
Proximity Weighted Riparian Disturbance (All Human Pressures)

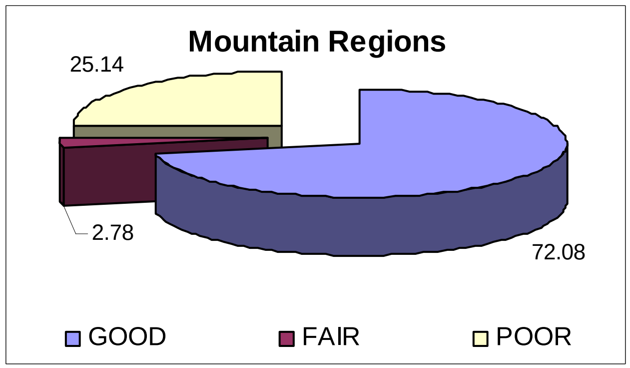


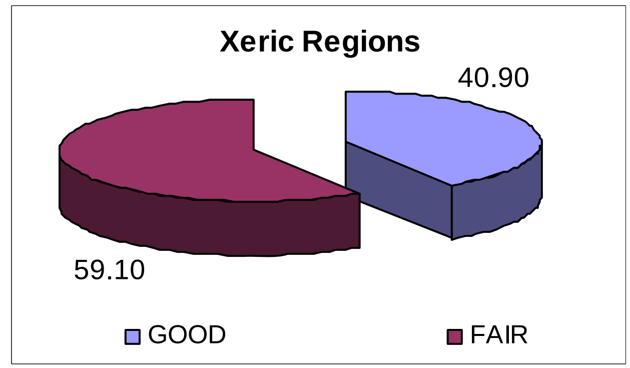




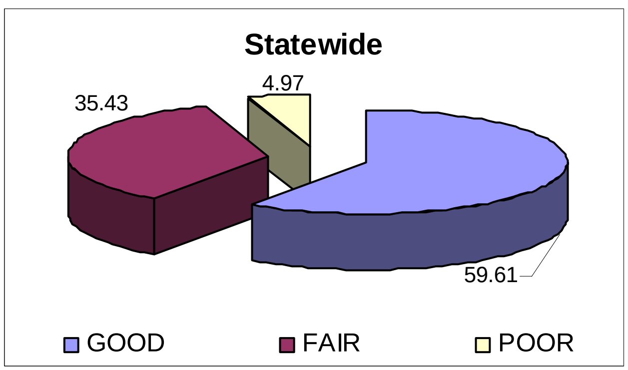
Proximity Weighted Riparian Disturbance (Sum of all Agriculture Pressures)

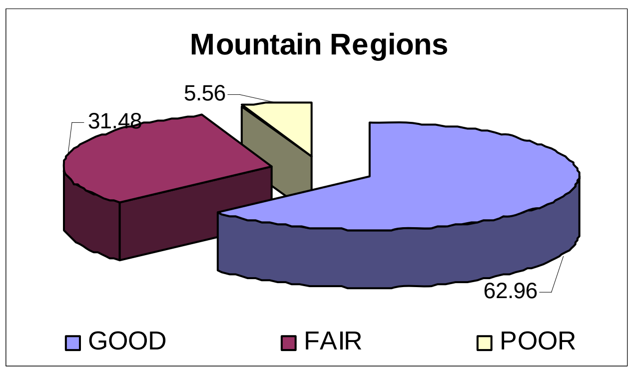


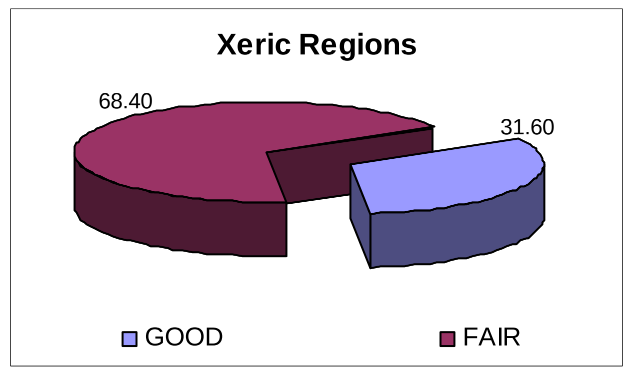




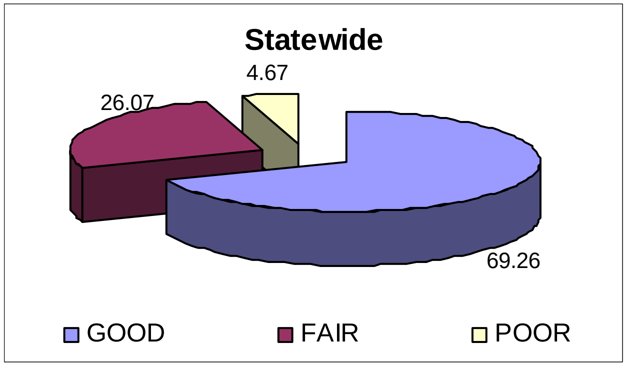
Riparian Habitat (Fraction of reach with 3-layers present)

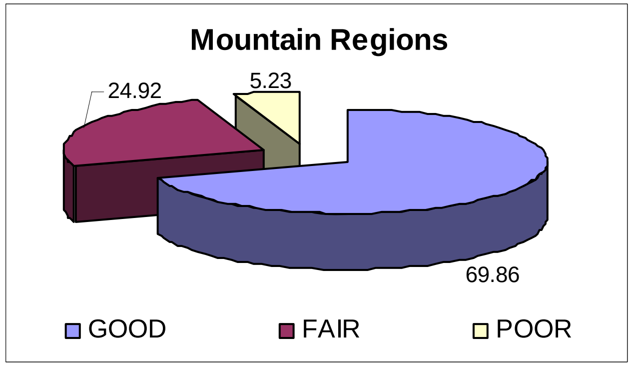


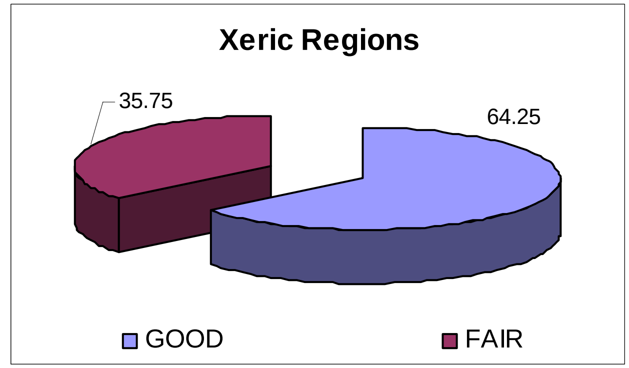




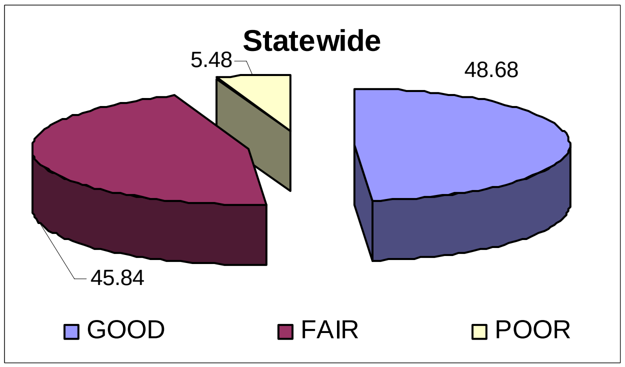
Mean Mid-Channel Canopy Density

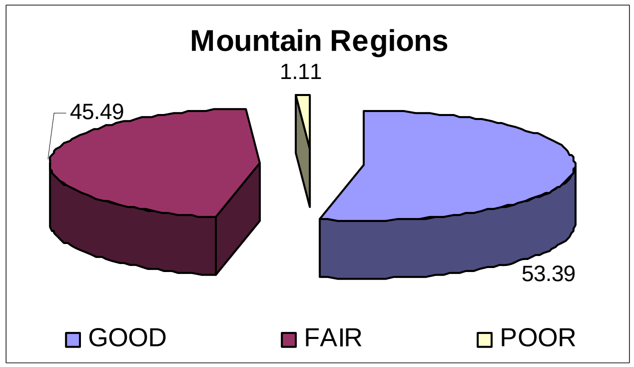


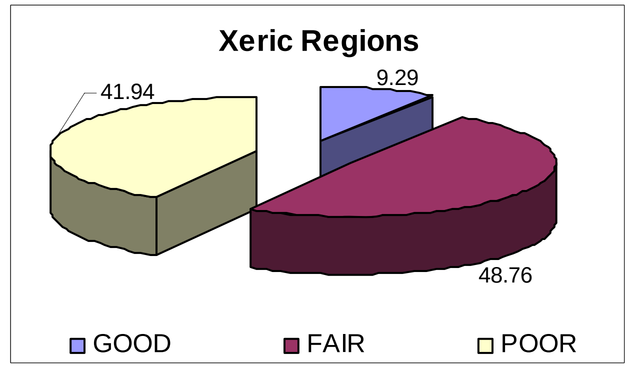




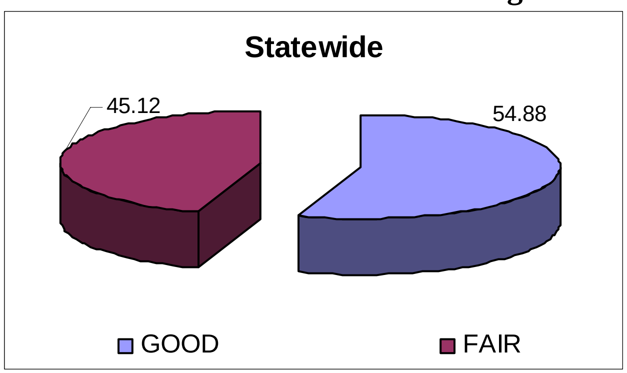
Fish Cover

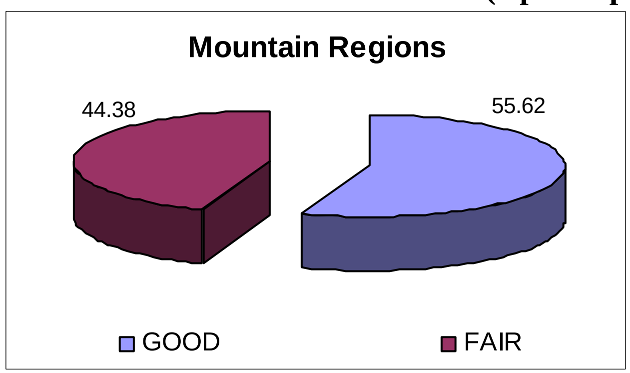


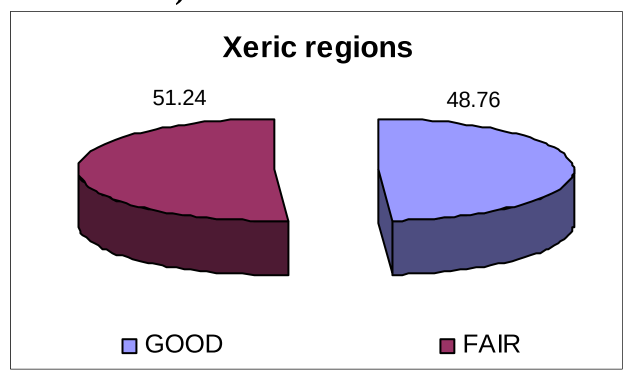




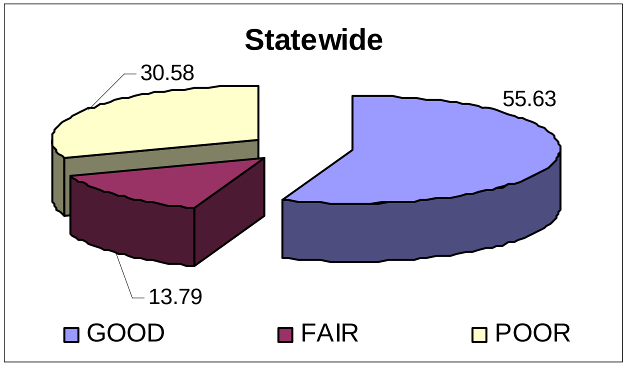
Large Woody Debris in/above Bankfull Channel (# pieces per 100 meters)

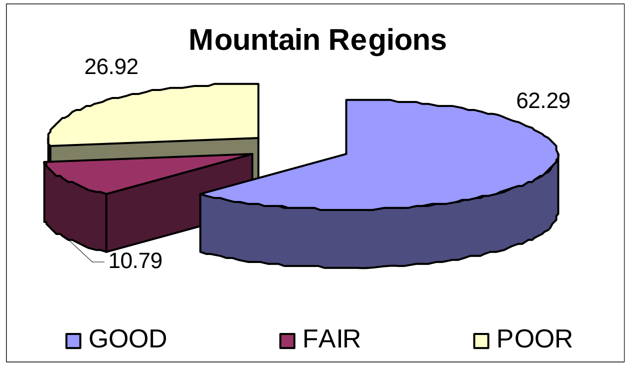


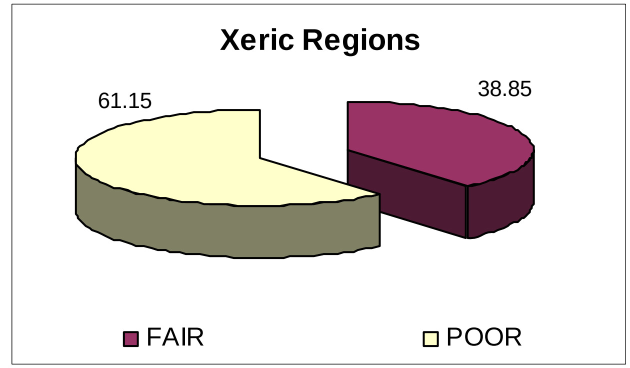




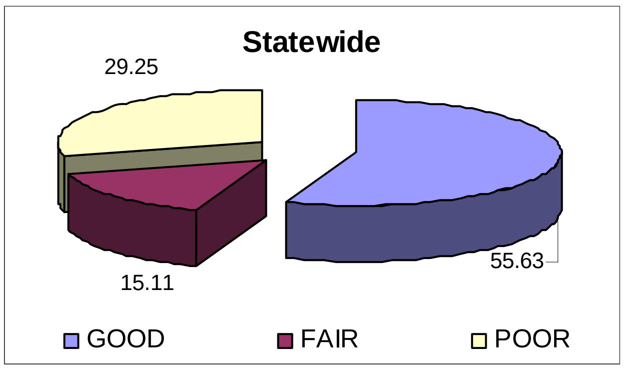
Fast Water Habitat (Percent of Riffles and Runs)

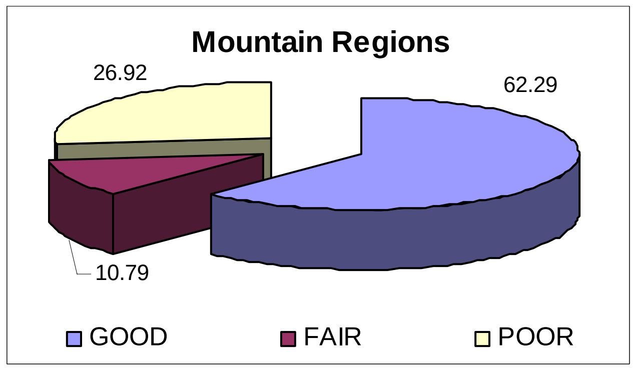


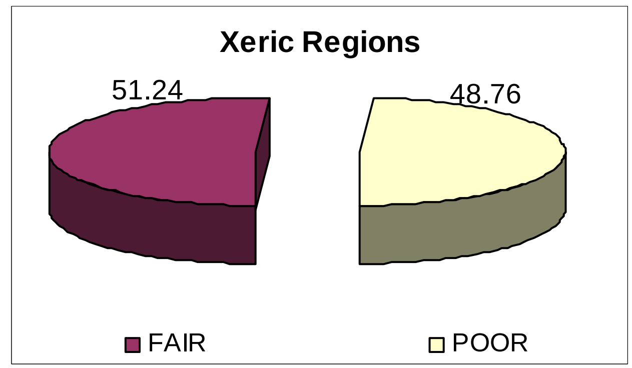




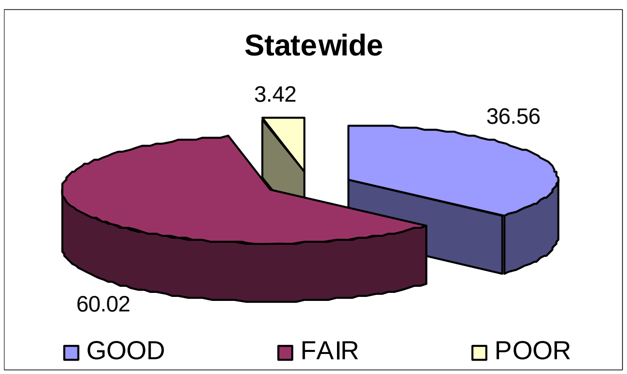
Slow Water Habitat (Percent of Glides and Pools)

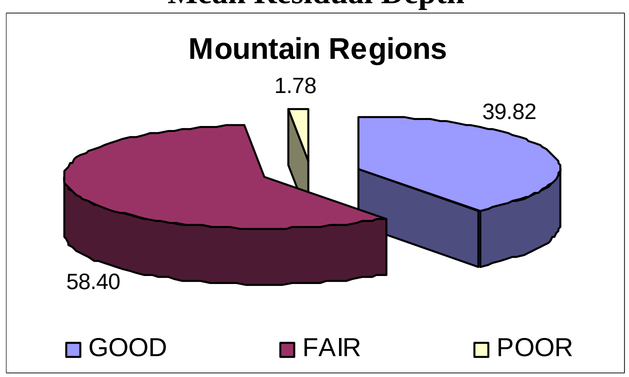


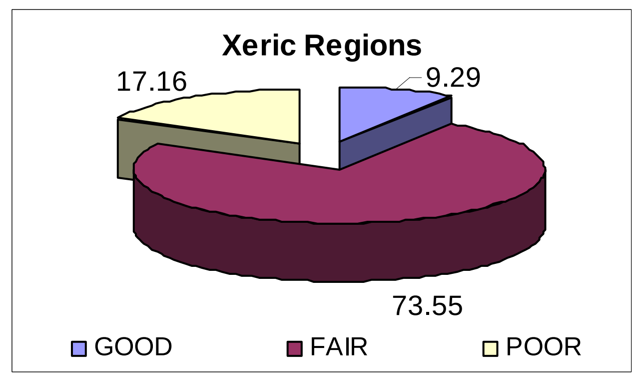




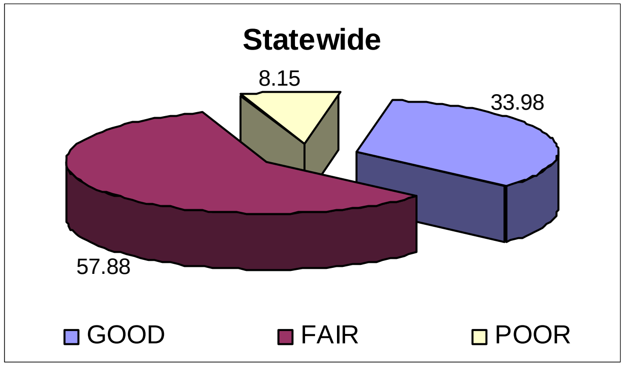
Mean Residual Depth

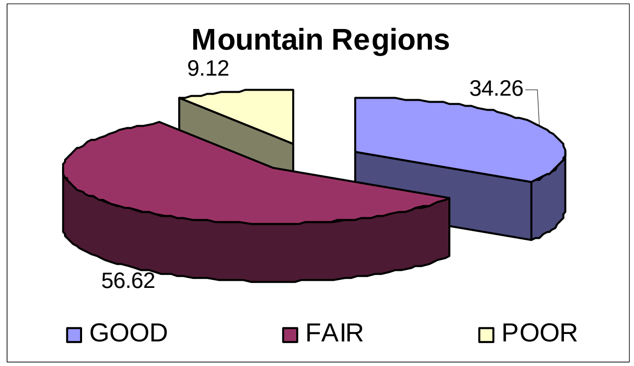


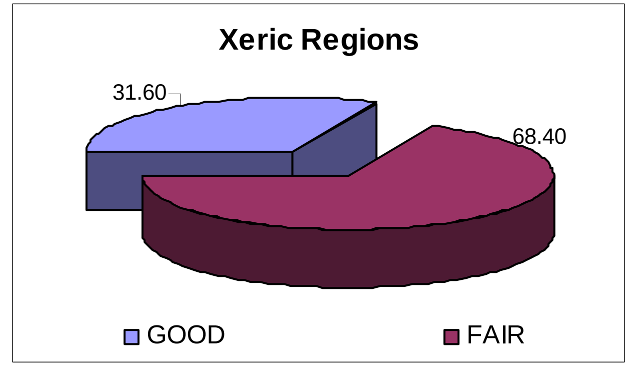




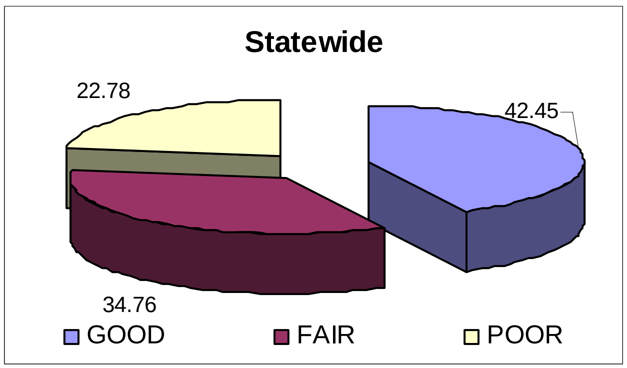
Relative Bed Stability

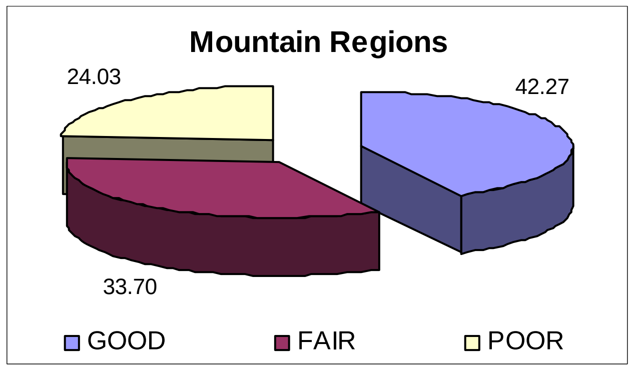


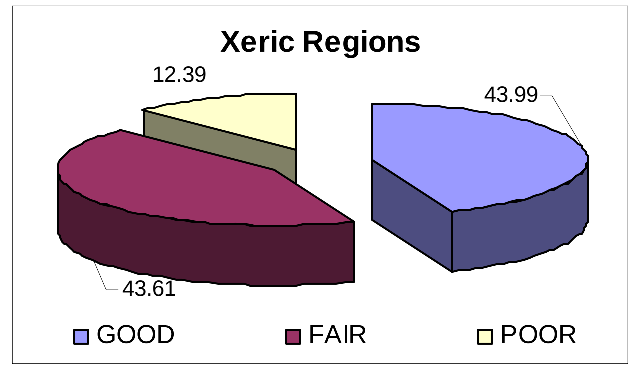




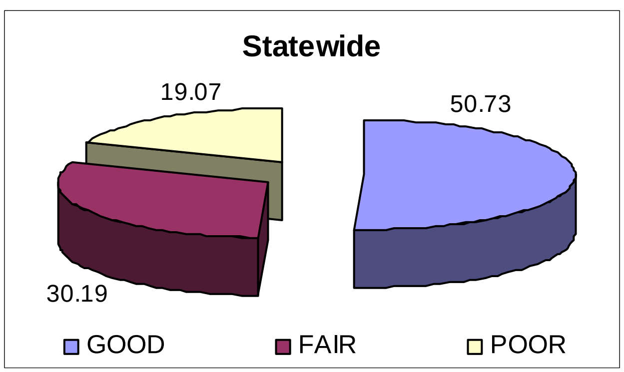
Embeddedness

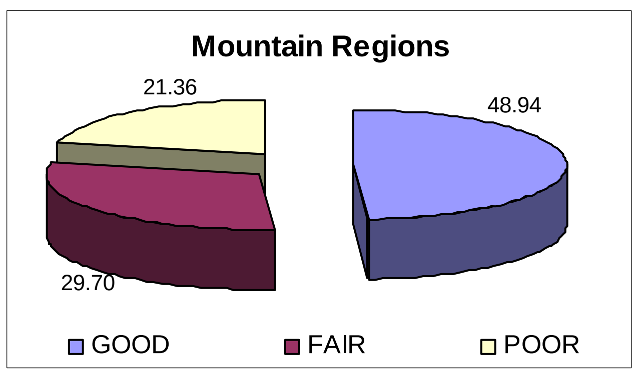


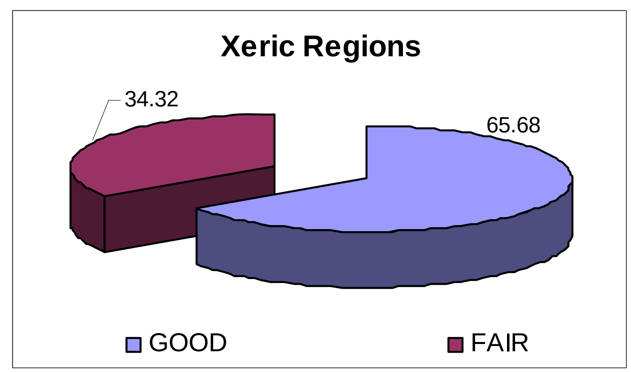




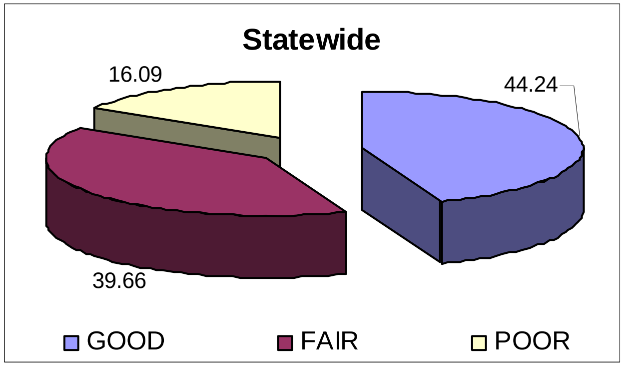
Percent of Substrate as Fines (Silt/Clay)

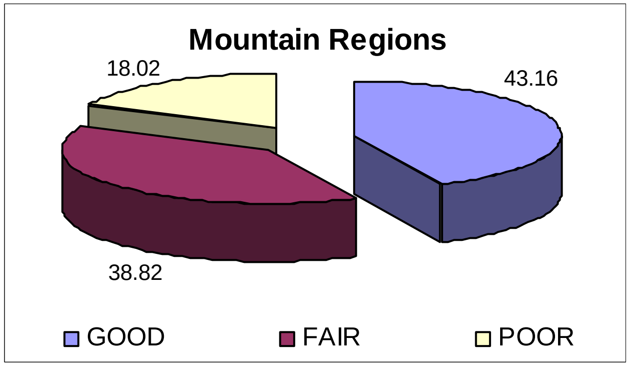


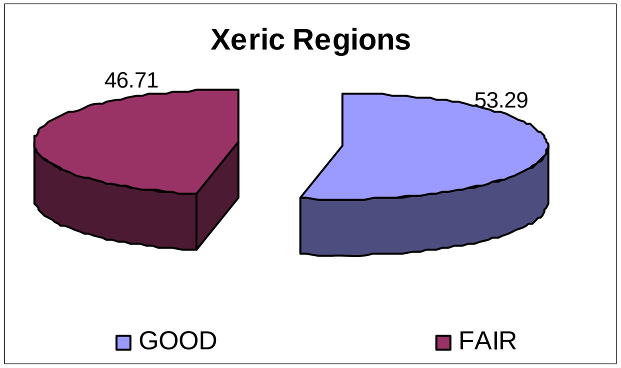




Percent of Substrate as Sand and Fines







B. Cumulative Distribution Functions for Physical and Chemical Stressors

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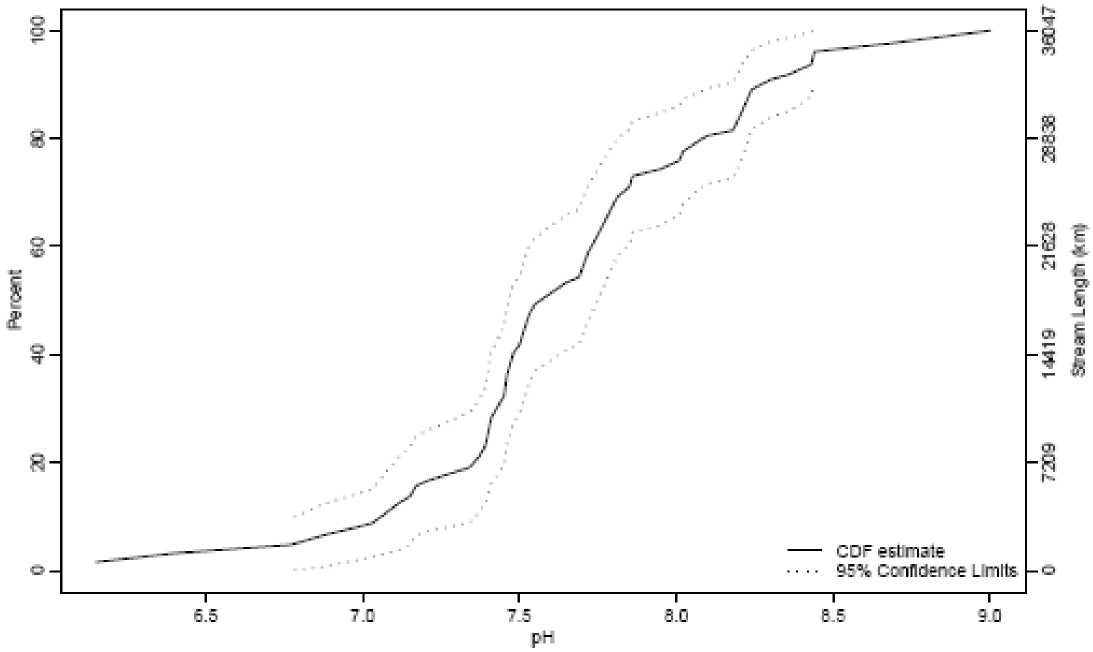
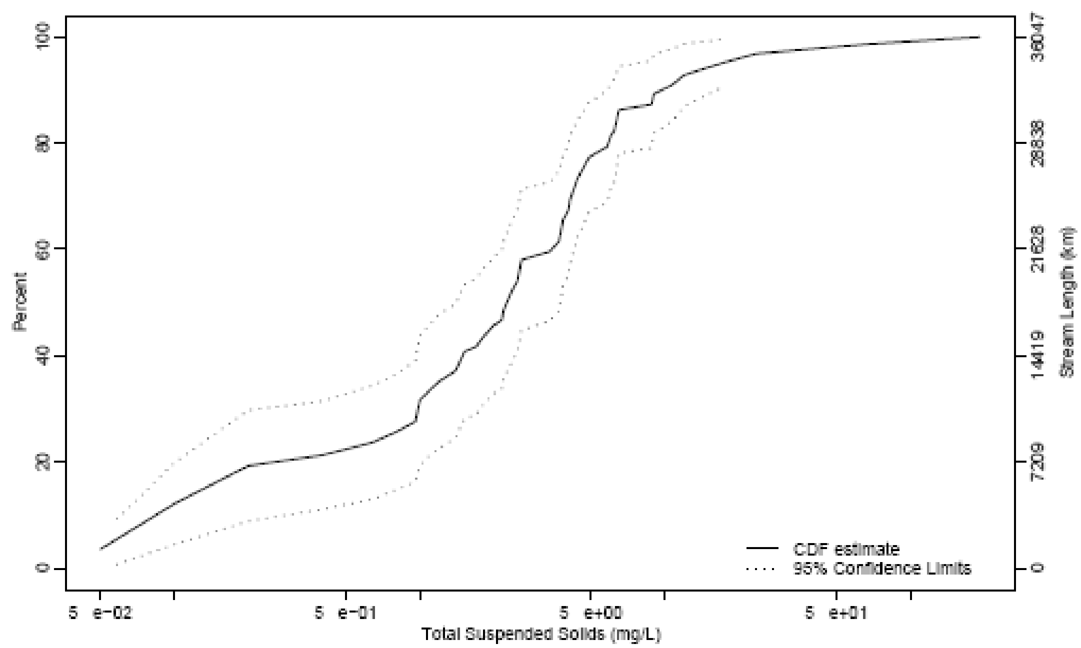
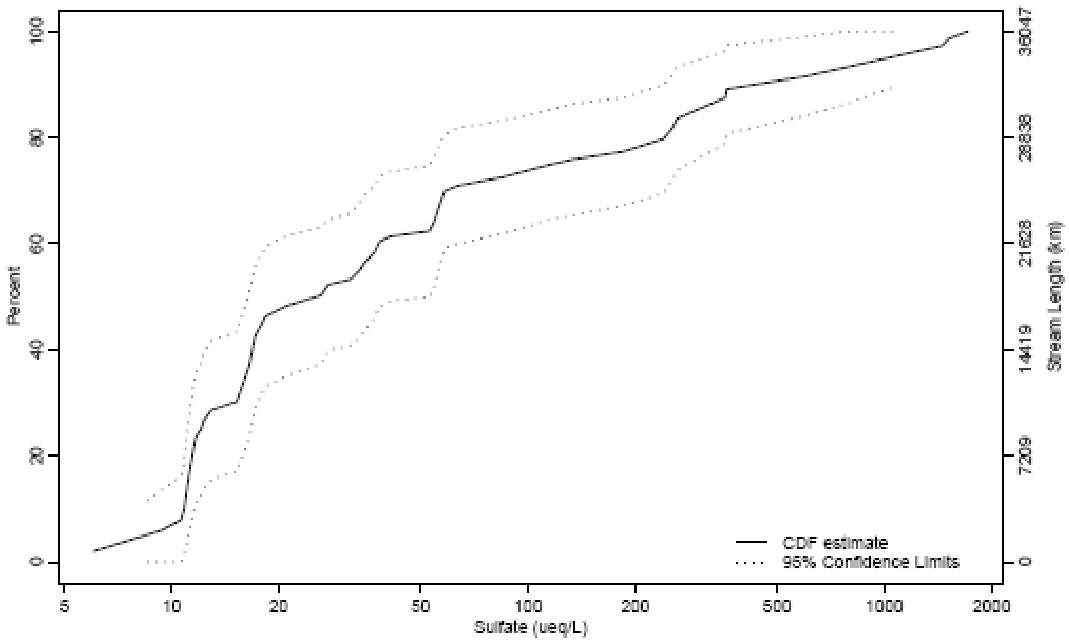
pH



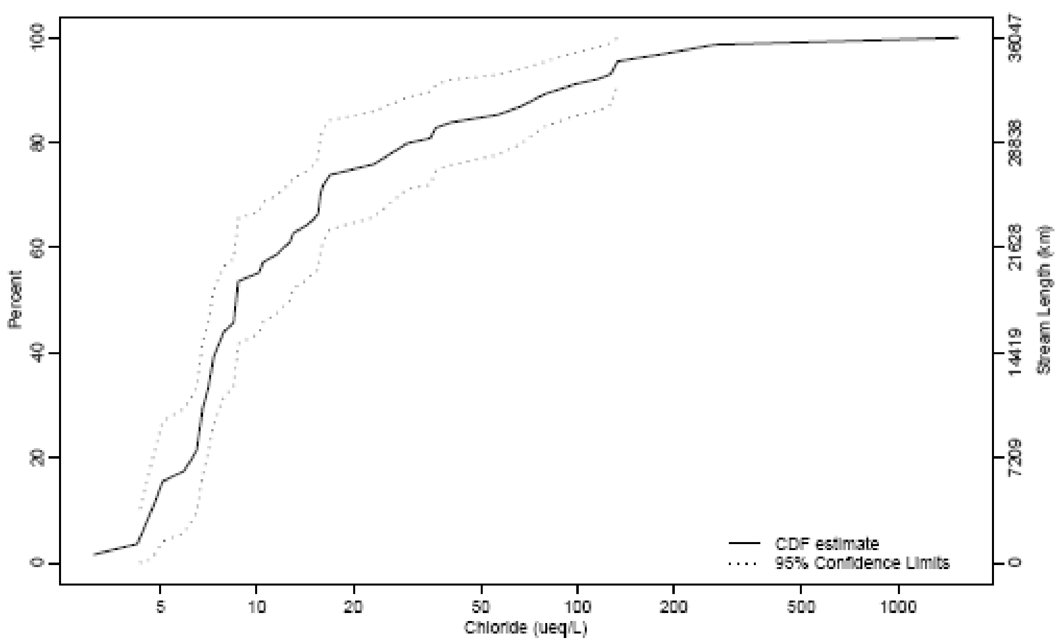
Total Suspended Solids



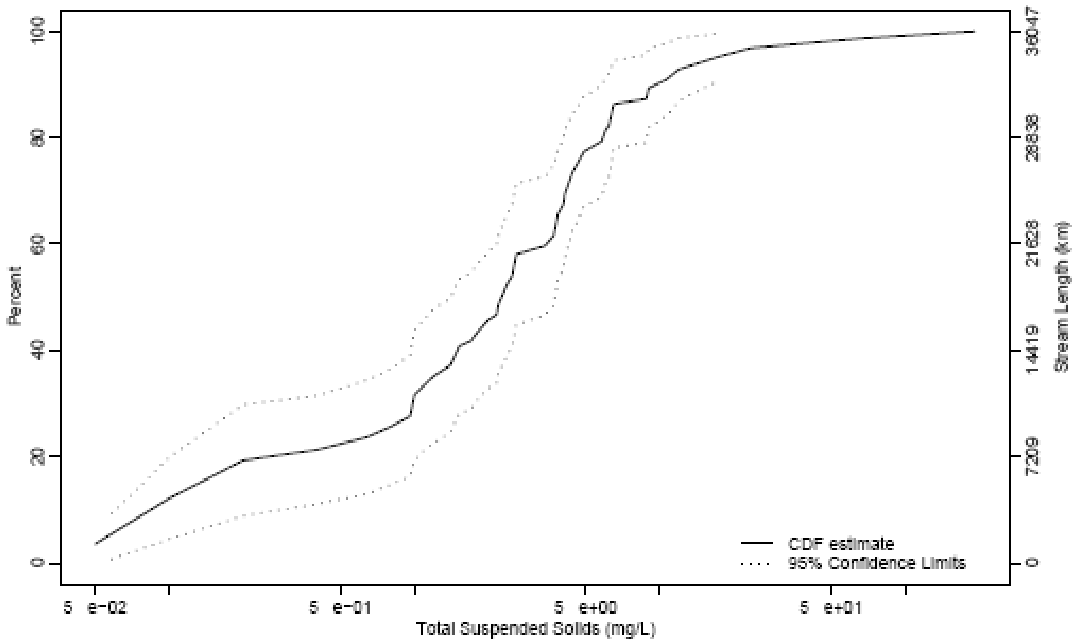
Sulfates



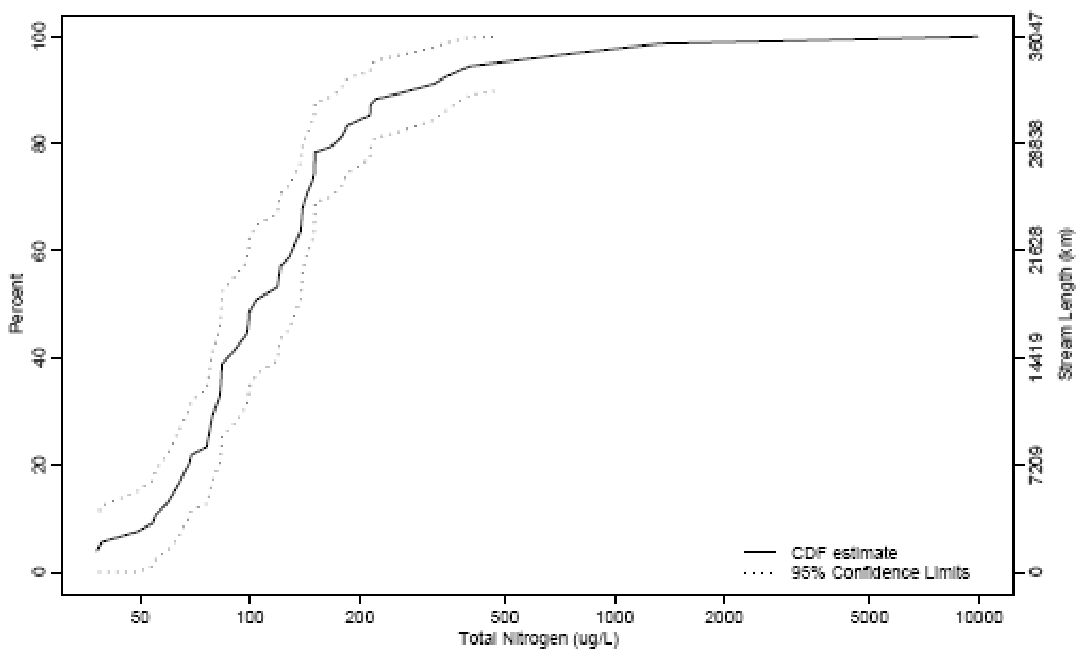
Chloride



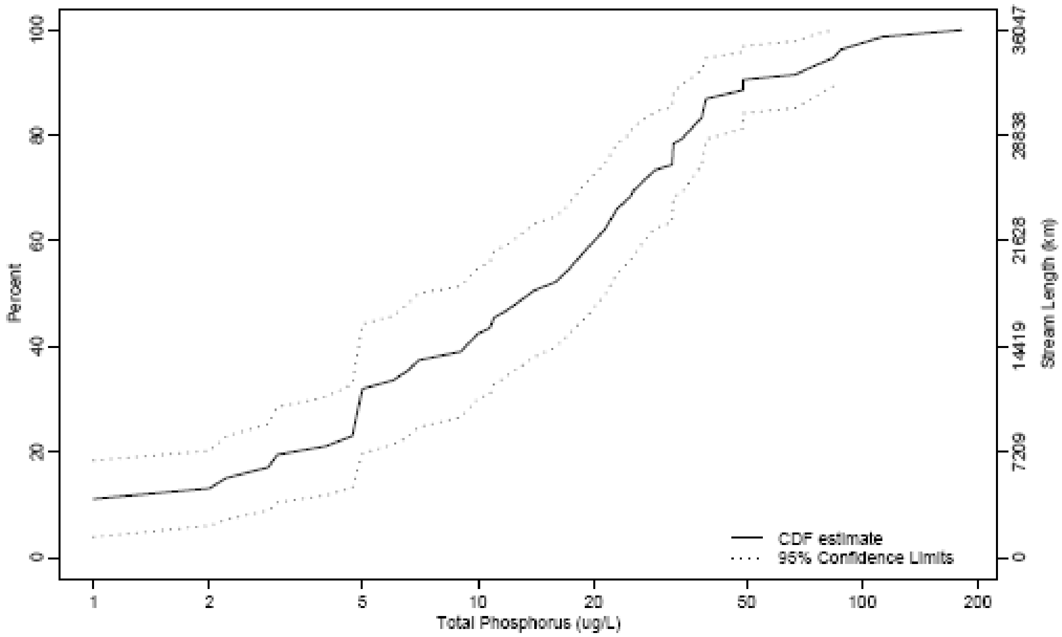
Total Suspended Solids



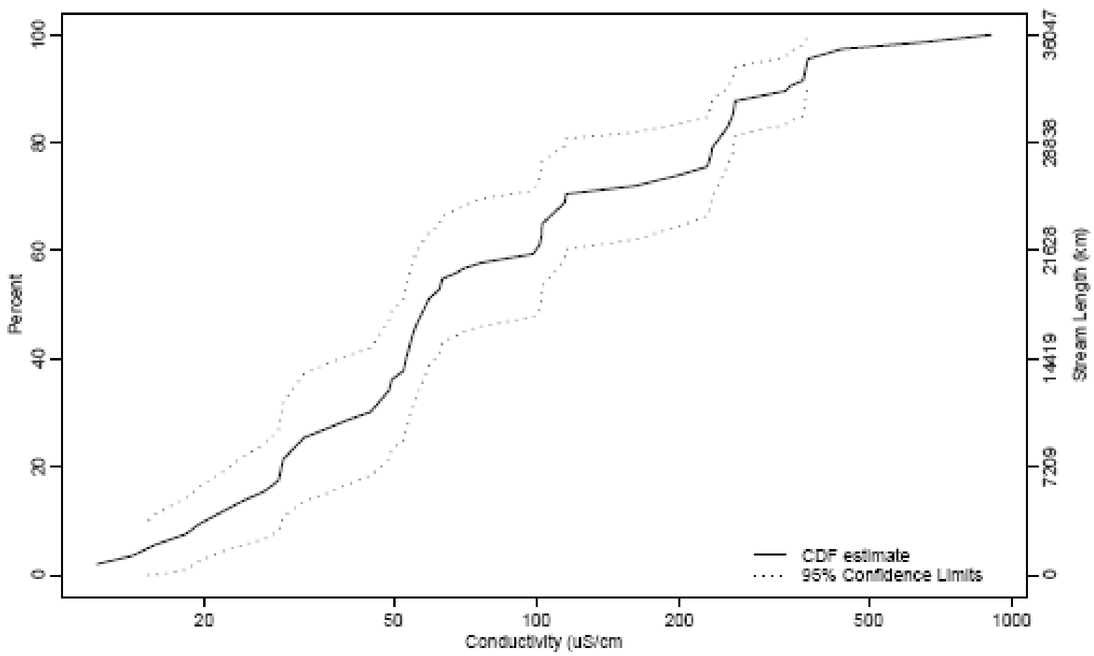
Total Nitrogen



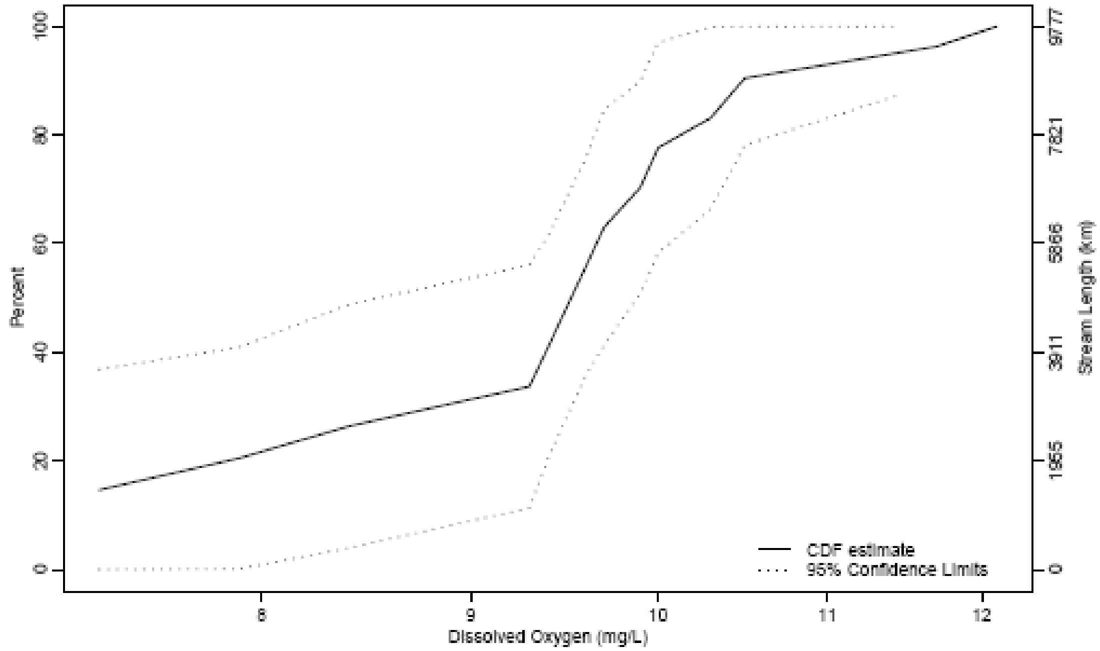
Total Phosphorus



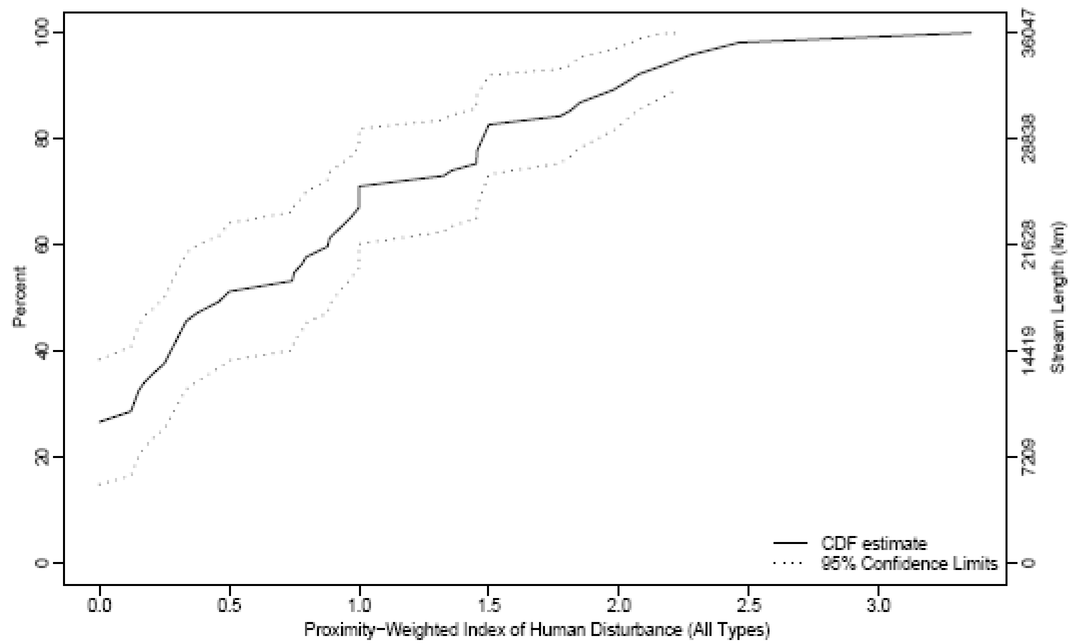
Conductivity



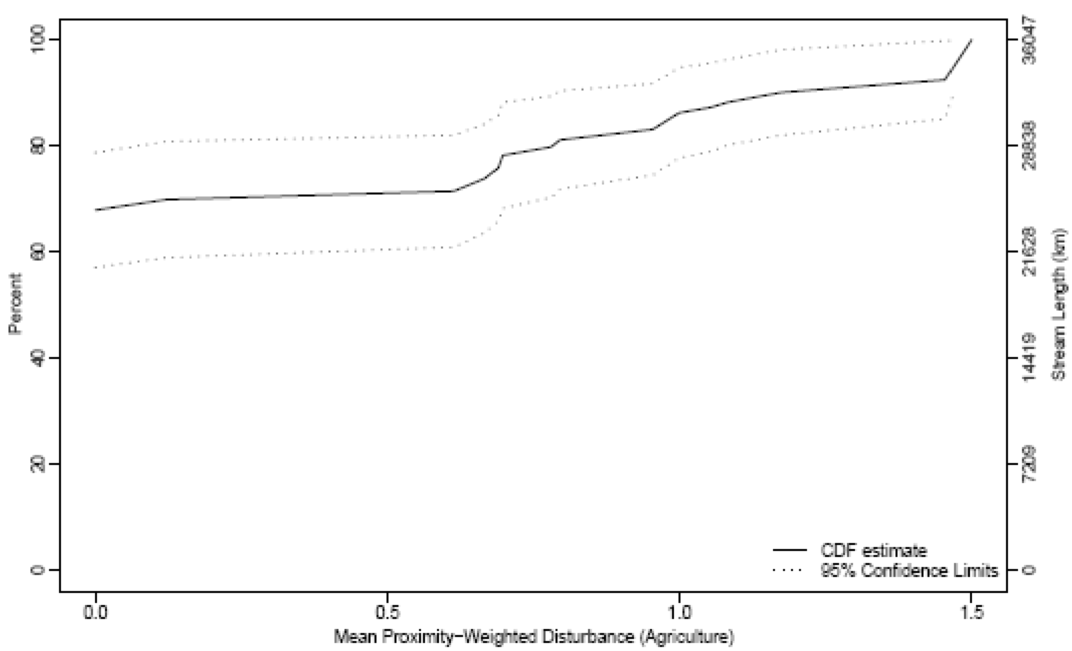
Dissolved Oxygen



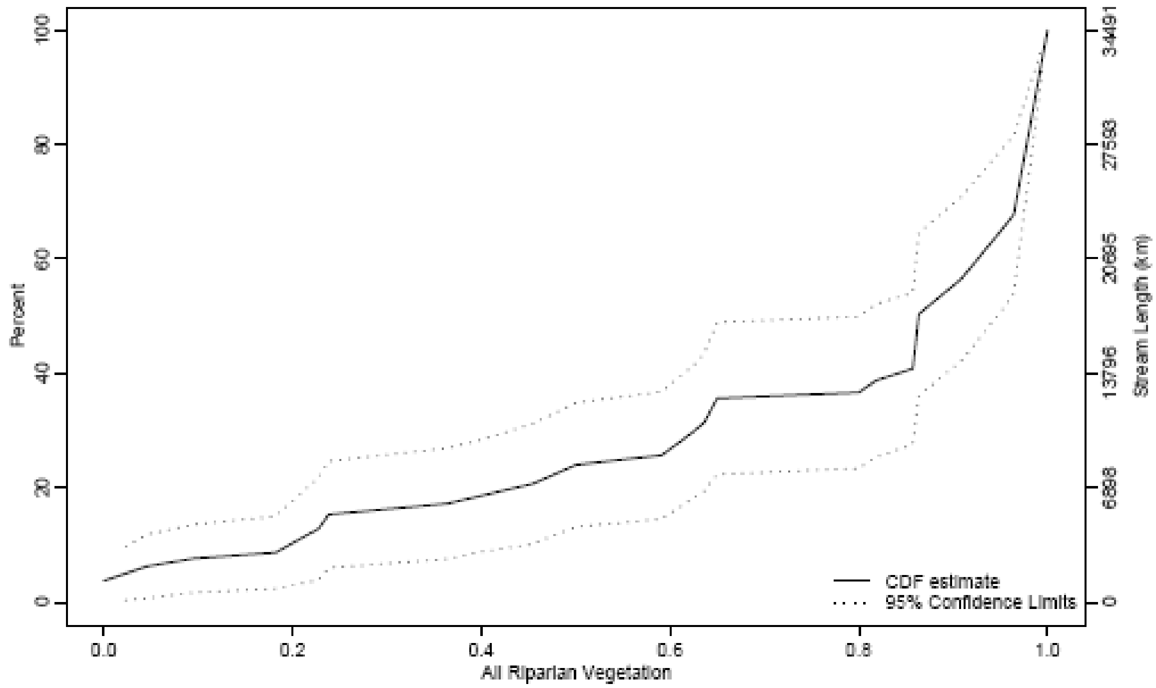
Proximity Weighted Riparian Disturbance (All Human Pressures)



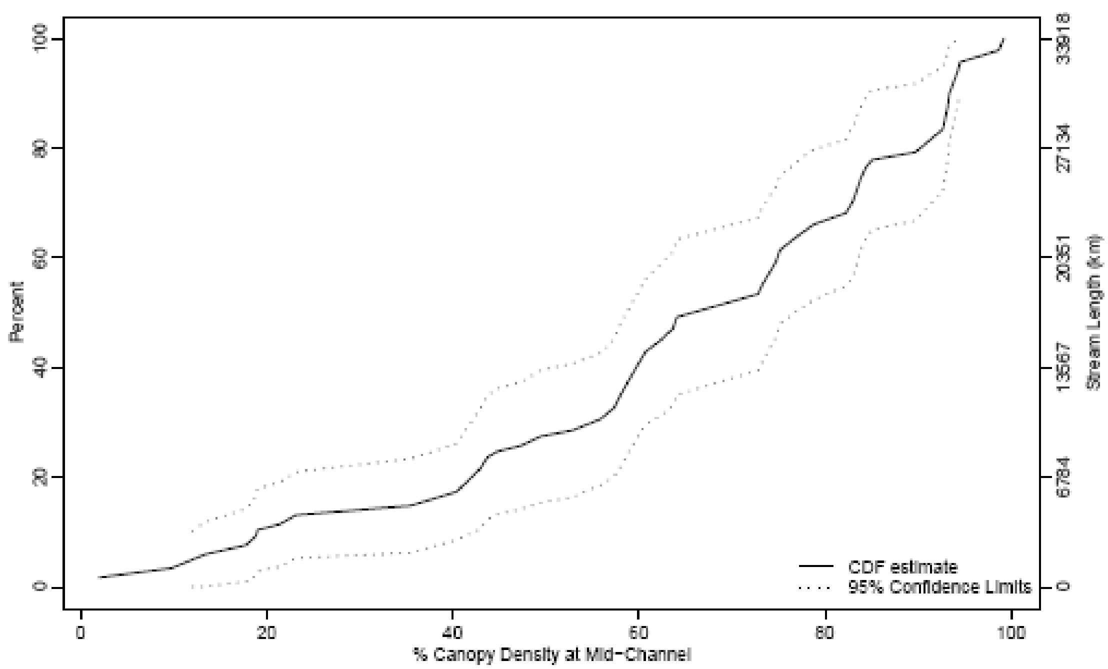
Proximity Weighted Riparian Disturbance (Ag Pressures)



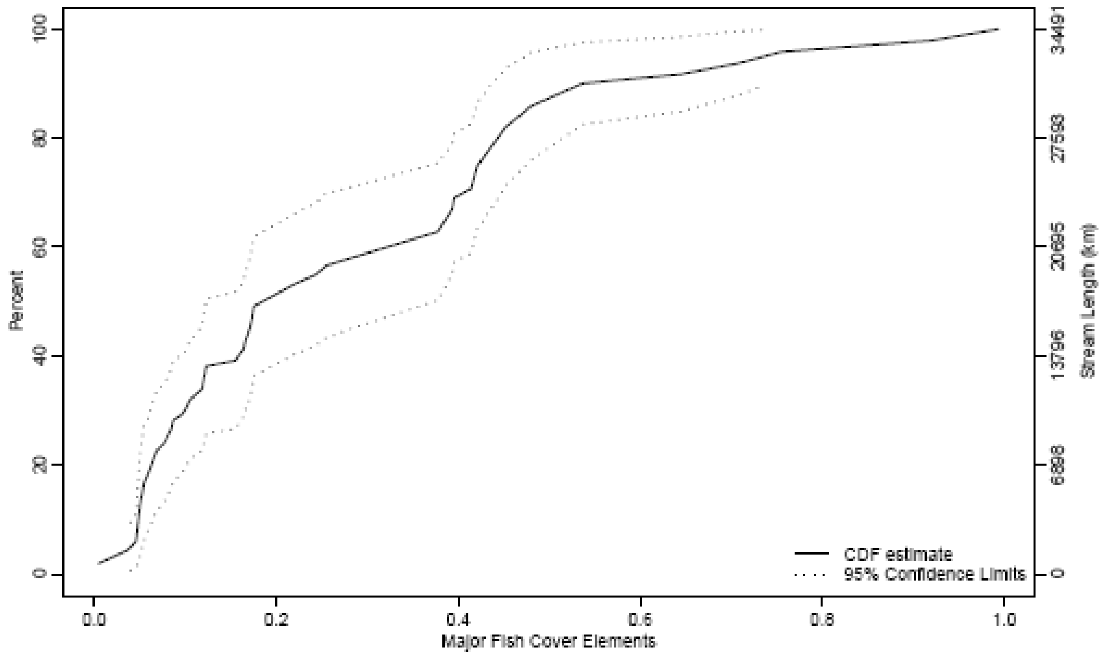
Riparian Habitat (Fraction of reach with 3 layers present)



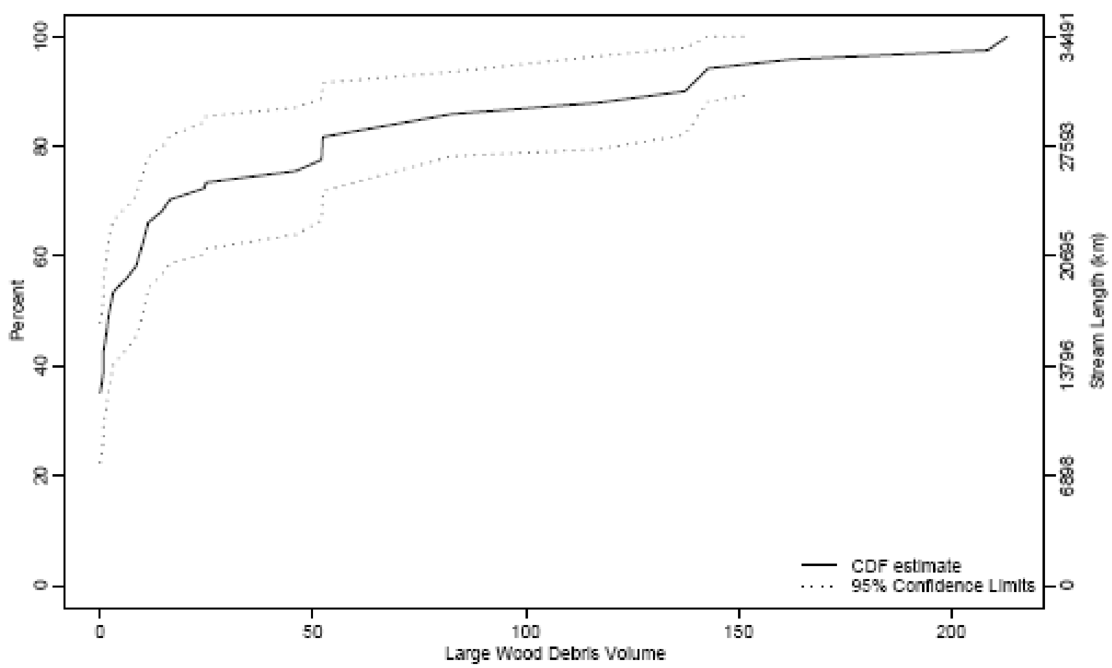
Mean Mid-Channel Canopy Density



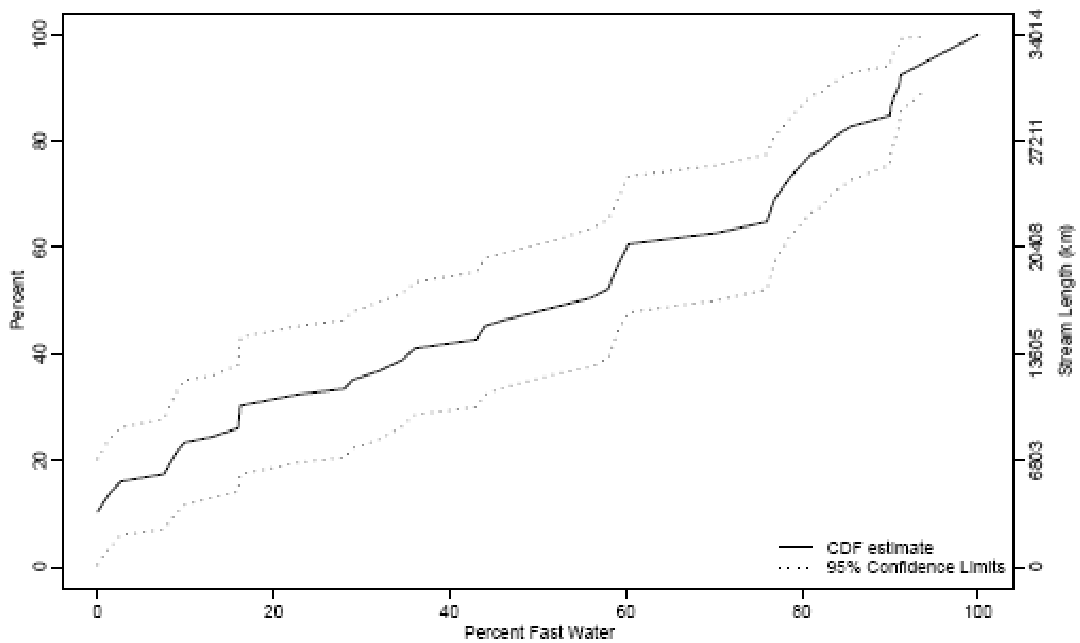
Fish Cover



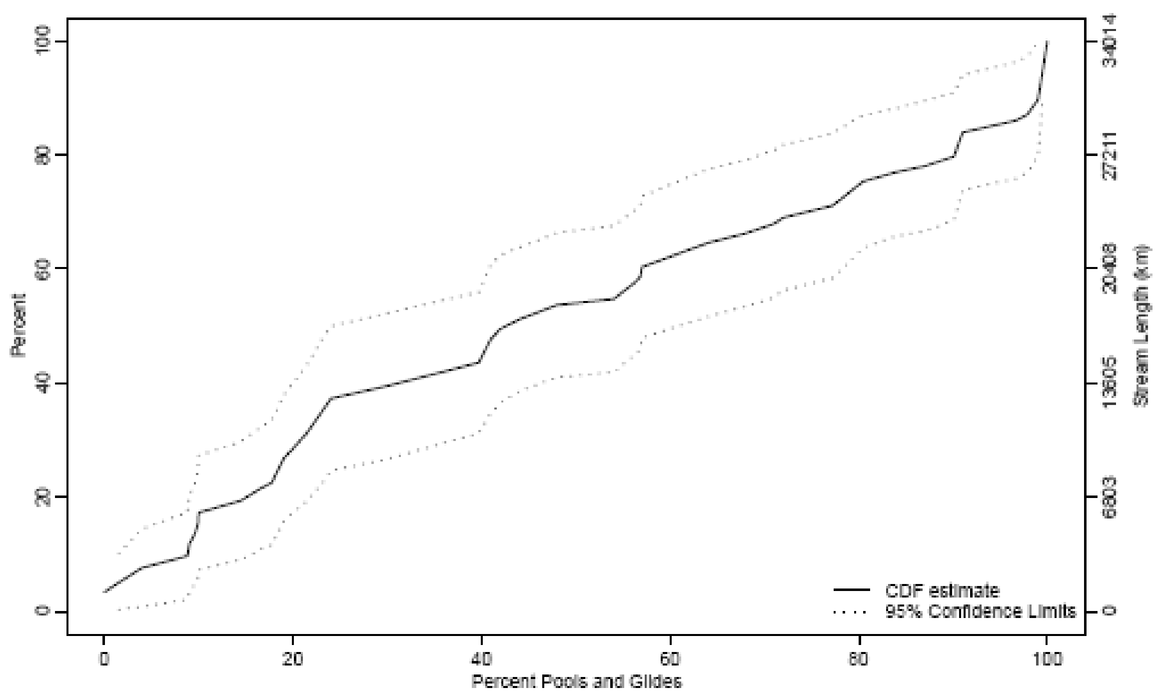
Large Woody Debris in/above Bankfull Channel (# pieces per 100 meters)



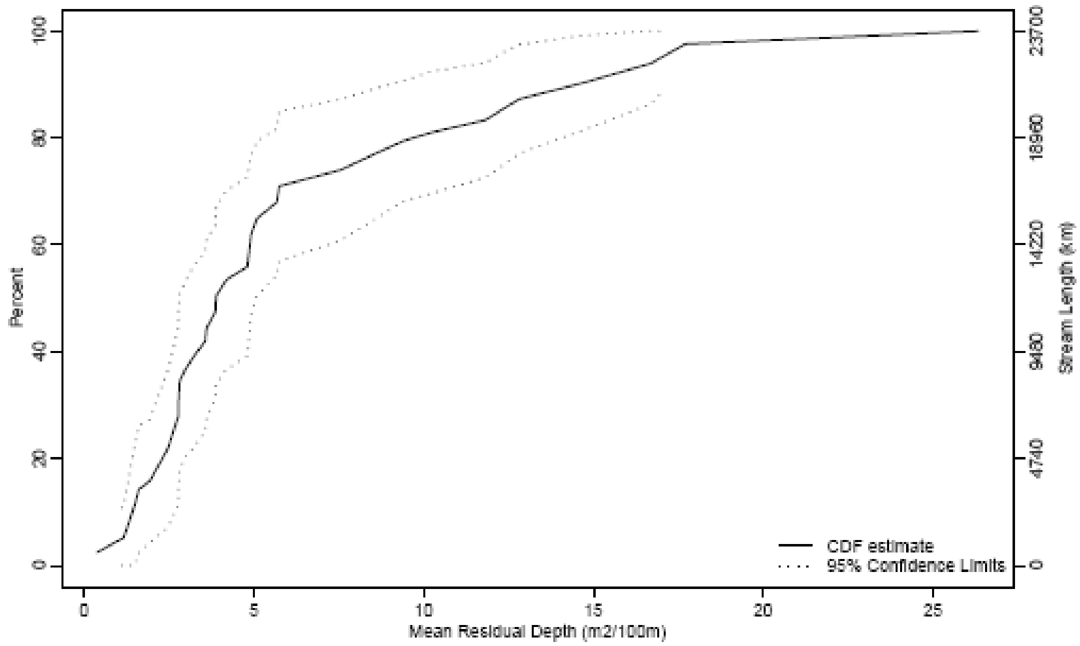
Fast Water Habitat (Percent of Riffles and Runs)



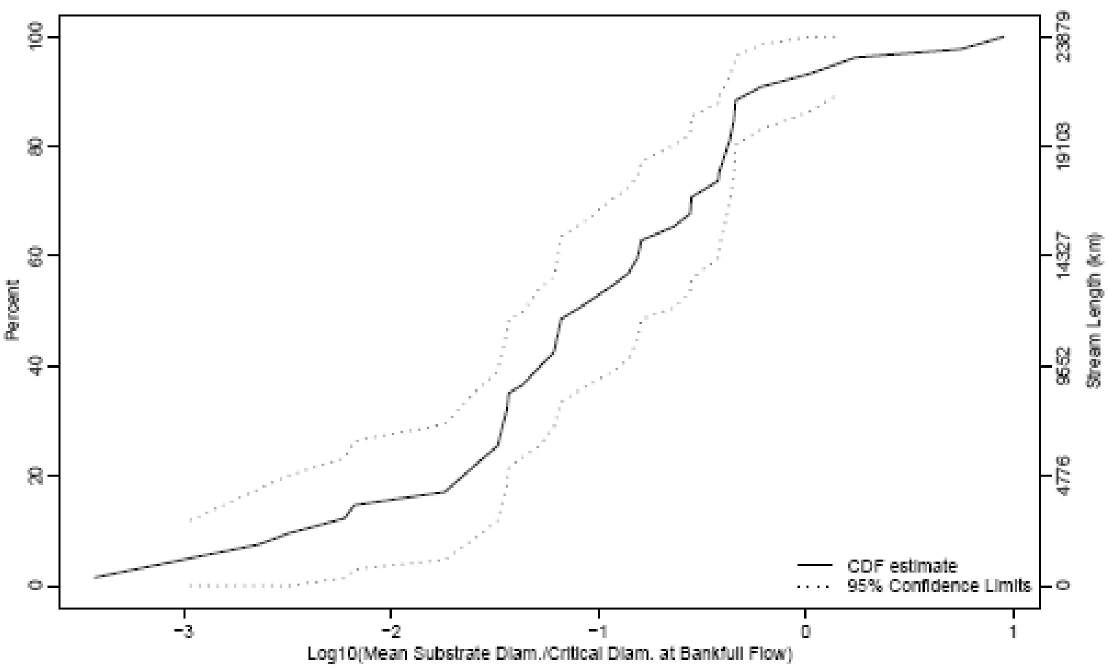
Slow Water Habitat (Percent of Glides and Pools)



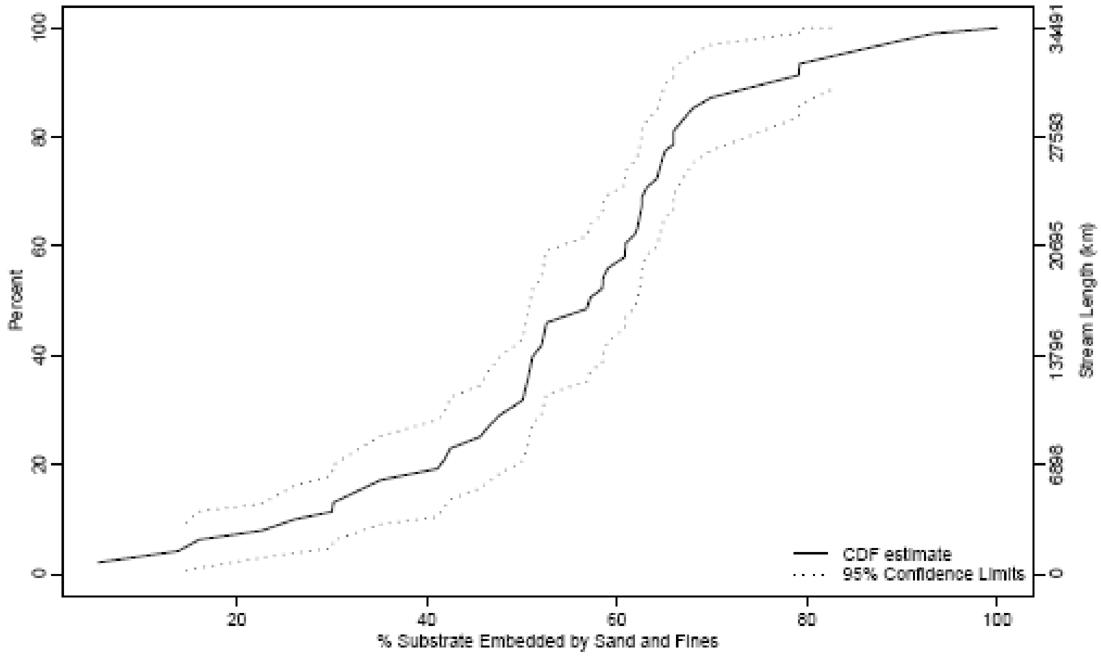
Mean Residual Depth



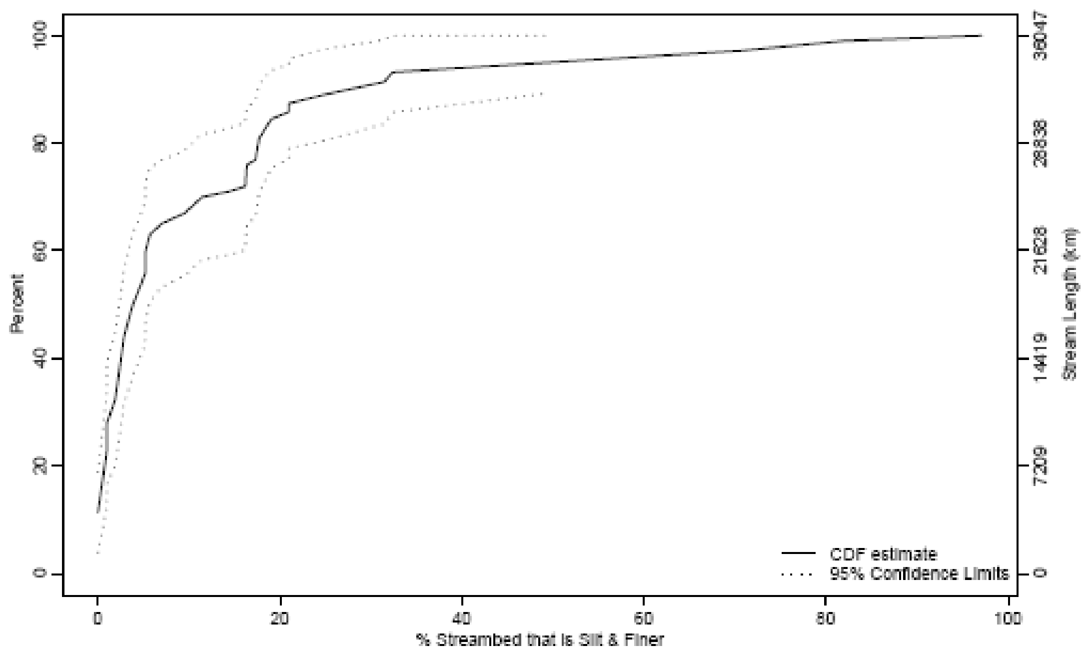
Relative Bed Stability



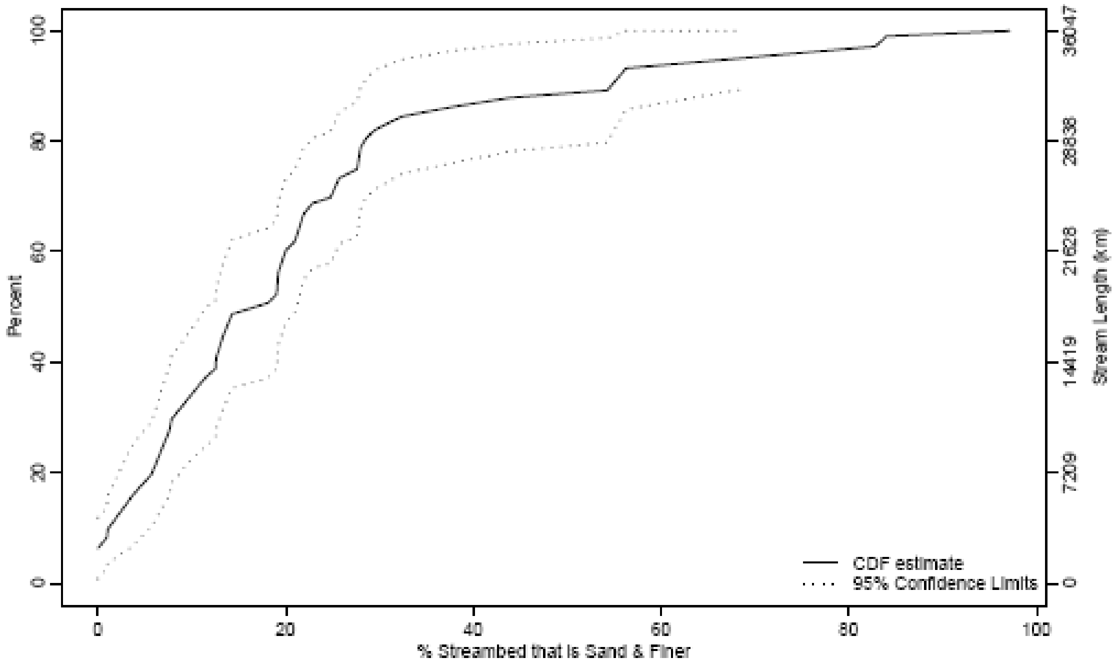
Embeddedness



Percent of Substrate as Silt/Clay (Fines)



Percent of Substrate as Sand and Fines



C. BURP to EMAP Comparison Plots

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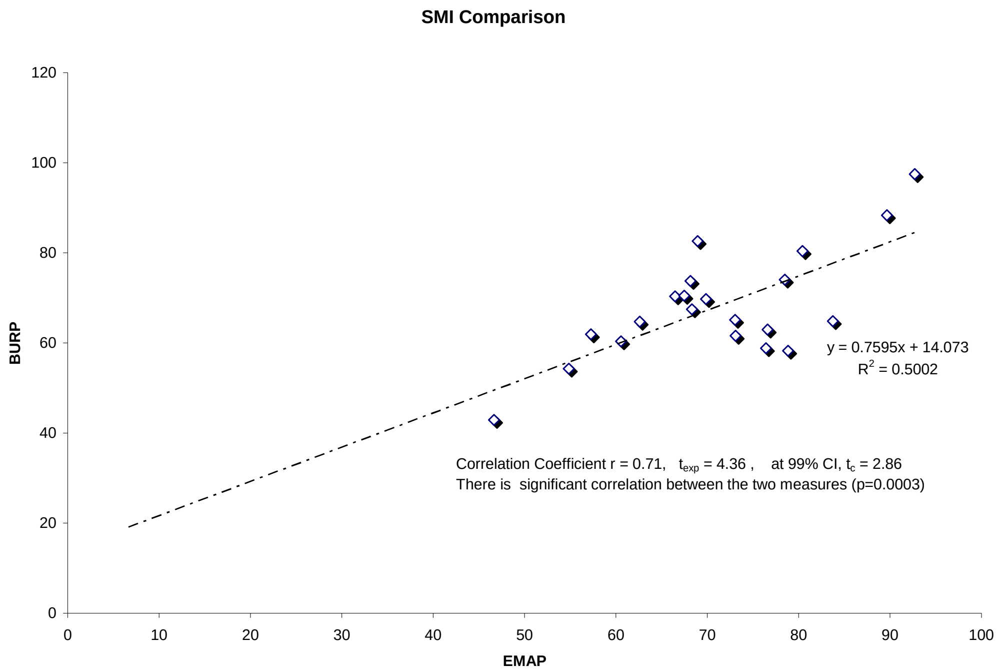
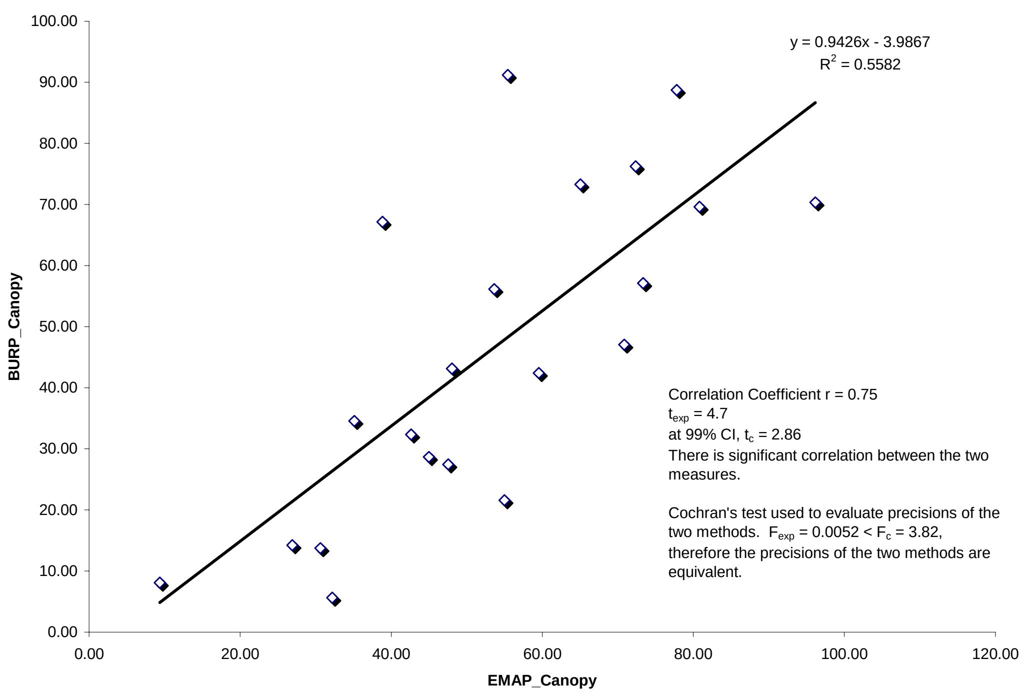
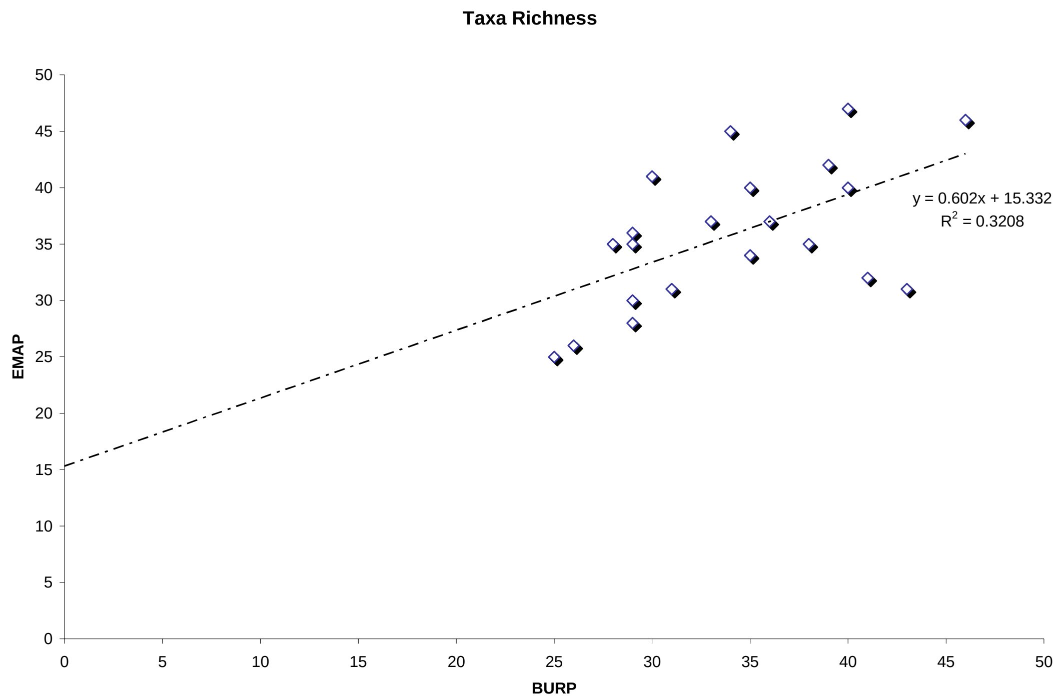
Macroinvertebrate Index Scores

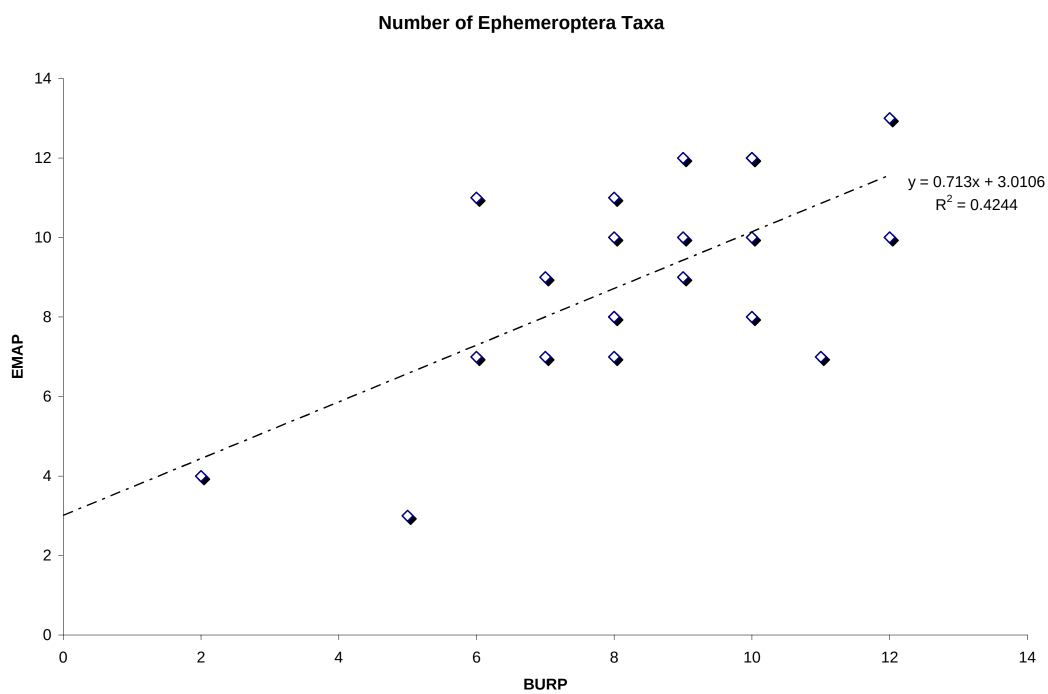


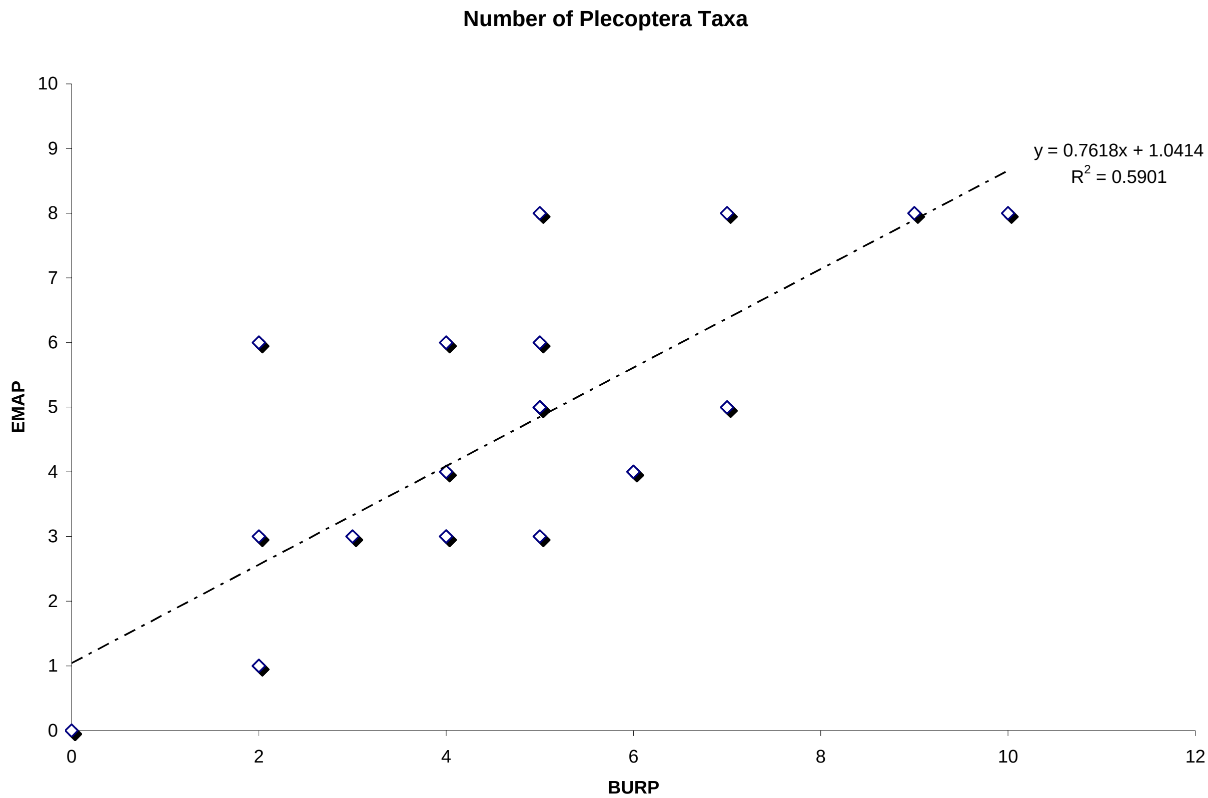
Canopy Cover

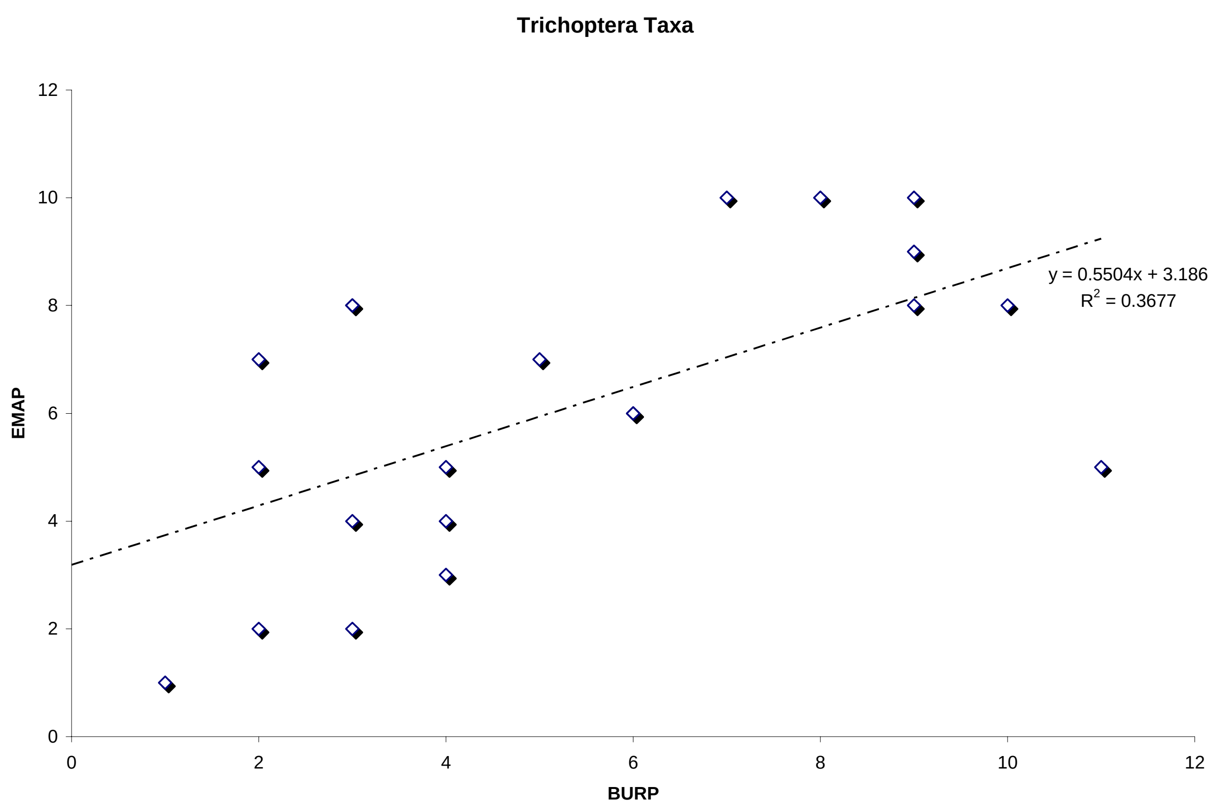


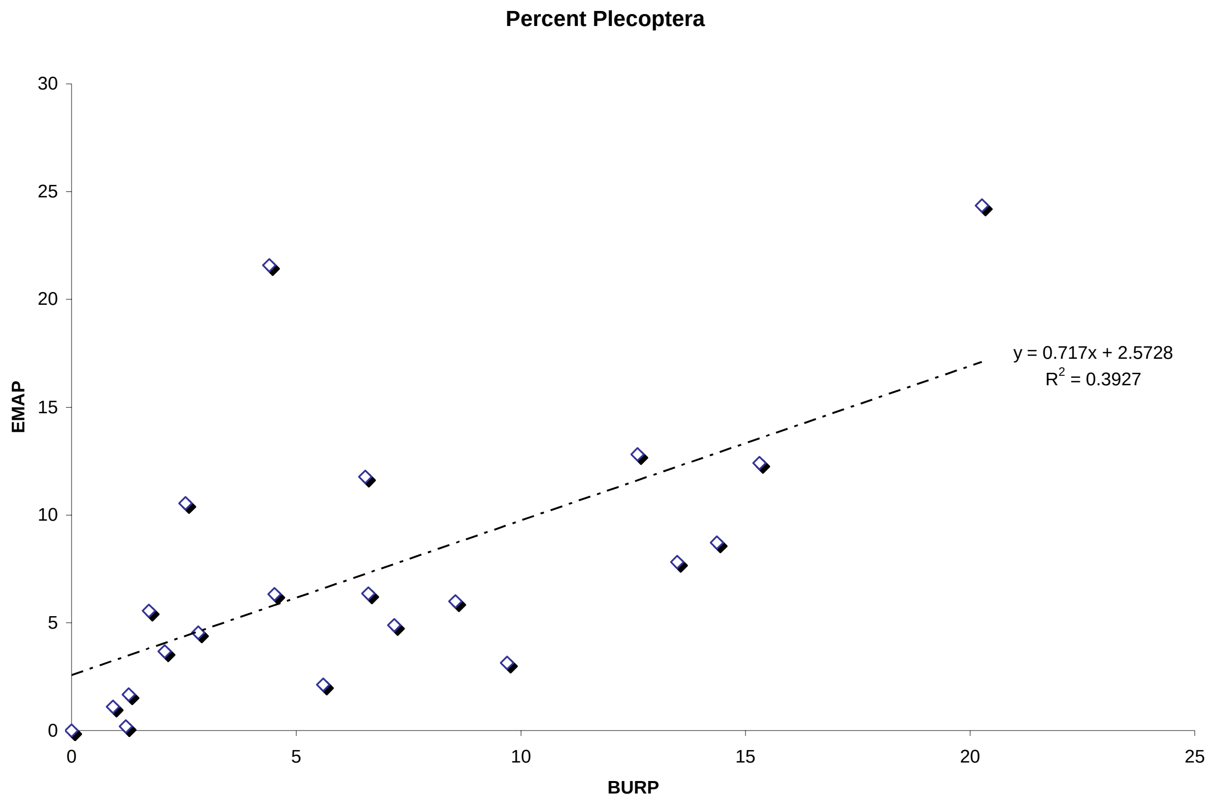
The following plots are for the metrics in the SMI

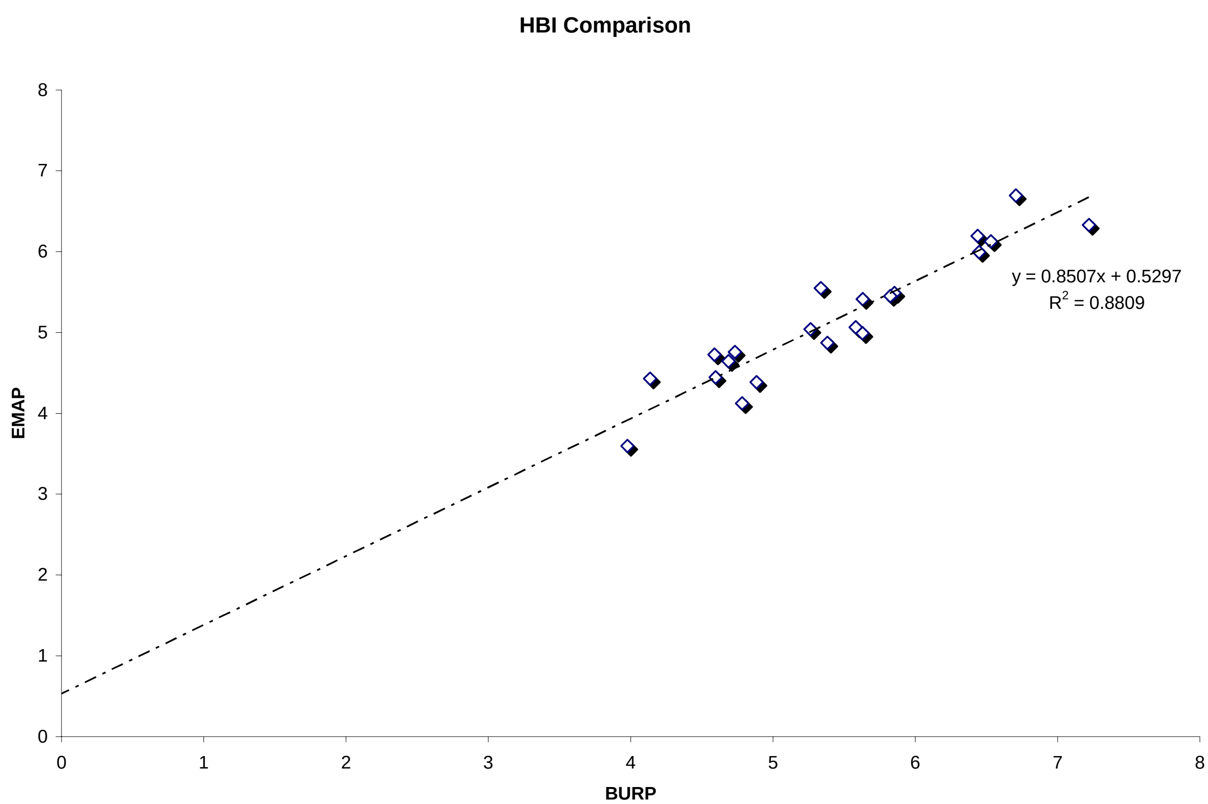


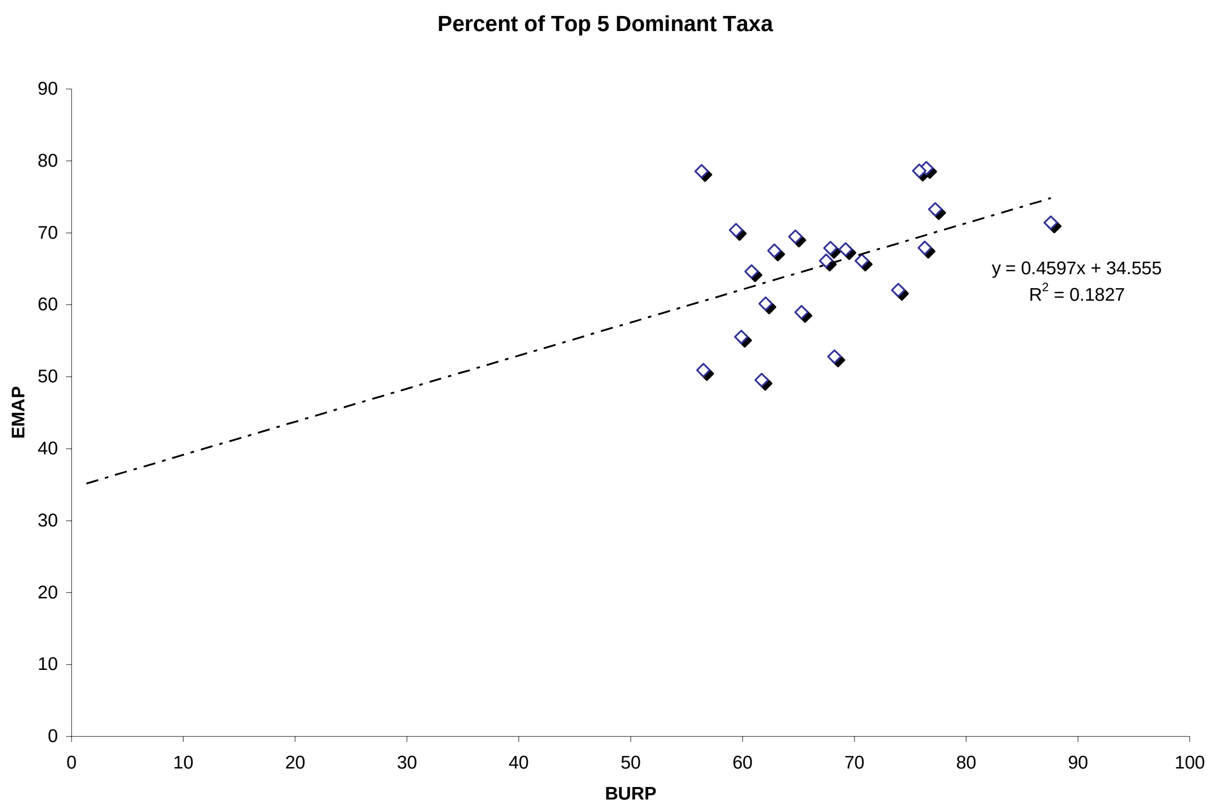


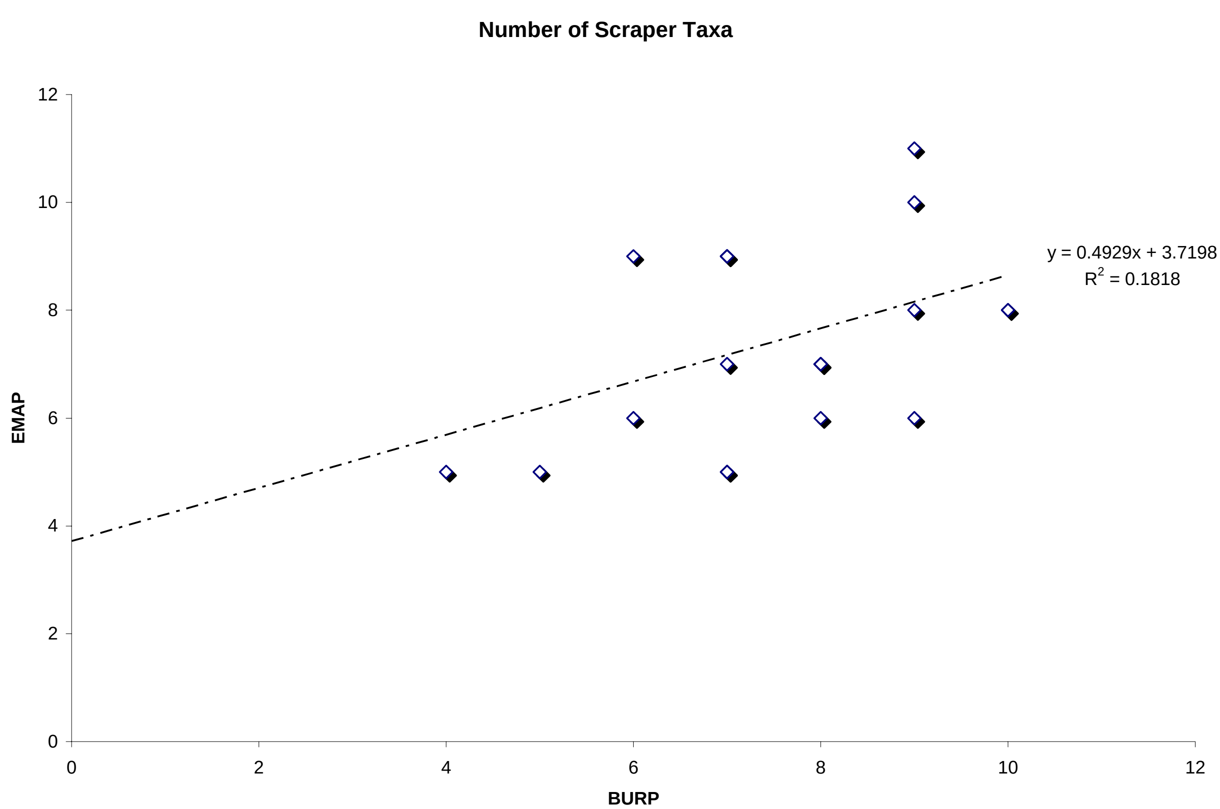

Number of Plecoptera Taxa
y = 0.7618x + 1.0414
R^2 = 0.5901
EMAP
BURP
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12

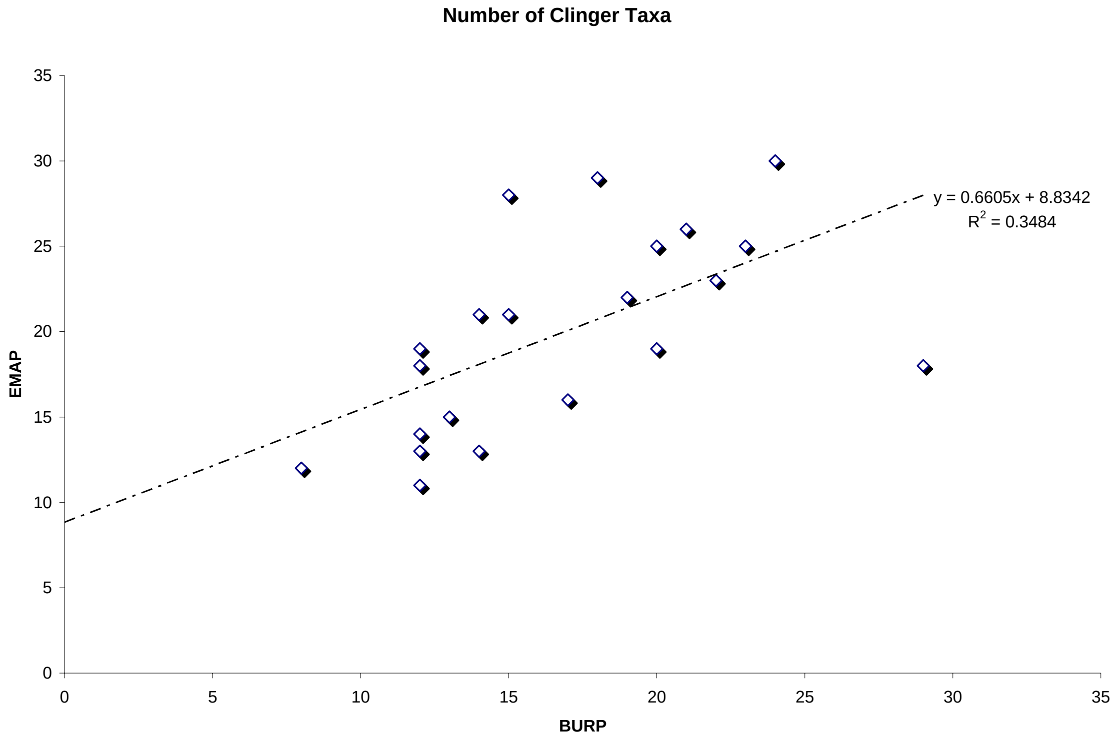

Trichoptera Taxa
y = 0.5504x + 3.186
R^2 = 0.3677
EMAP
BURP
0
2
4
6
8
10
12
0
2
4
6
8
10
12


Percent Plecoptera
EMAP
BURP
y = 0.717x + 2.5728
R2 = 0.3927
0
5
10
15
20
25
30


HBI Comparison
EMAP
BURP
y = 0.8507x + 0.5297
R2 = 0.8809
0
1
2
3
4
5
6
7
8


Percent of Top 5 Dominant Taxa
EMAP
BURP
0
10
20
30
40
50
60
70
80
90
100
y = 0.4597x + 34.555
R2 = 0.1827


Number of Scraper Taxa
EMAP
BURP
0
2
4
6
8
10
12
y = 0.4929x + 3.7198
R2 = 0.1818


Number of Clinger Taxa
35
30
25
20
15
10
5
0
EMAP
0
5
10
15
20
25
30
35
BURP
y = 0.6605x + 8.8342
R2 = 0.3484

D. Physical Habitat Metric Sensitivity

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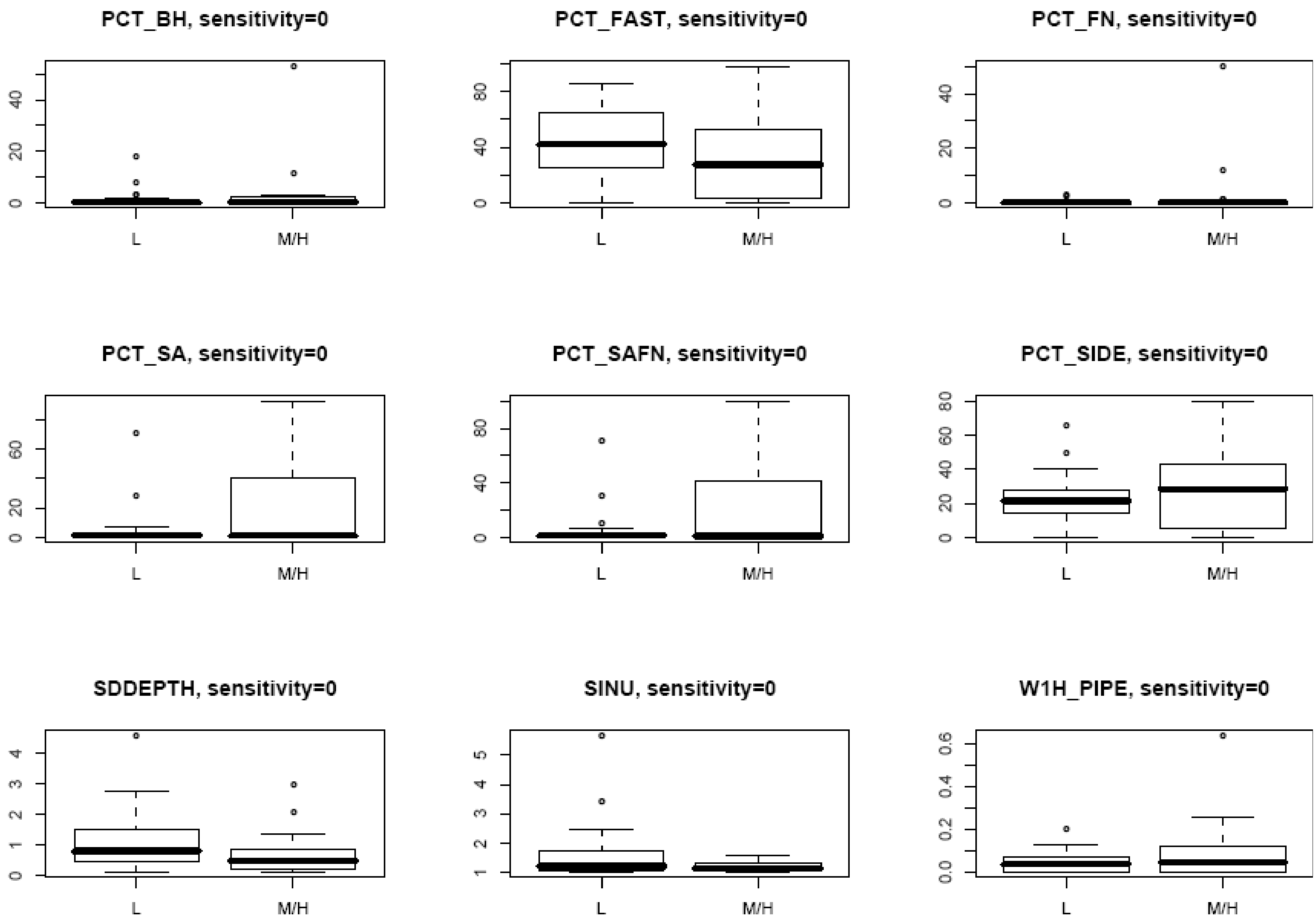
Sensitivity of physical habitat metrics to detect impairment status. Highly sensitive (3) metrics had no overlap of interquartile ranges between least-impacted and moderately/highly-impacted groups. Variables with missing values or too few unique values (e.g., almost all zeros) were omitted.

Metric	Metric Sensitivity	Definition
PCAN_C	3	Riparian Canopy Coniferous (Fract reach)
PCT_POOL	**3**	**Pools -- All Types (% of reach)**
W1_HAG	3	Rip Dist--Sum Agric Types (ProxWt Pres)
XBKF_H	3	Bankfull Height-Mean (m)
XFC_ALG	**3**	**Lit. cover-fil. Algae (Areal Prop)**
XFC_AQM	3	Lit. cover-aq. Macrophyte(Areal Prop)
XFC_OHV	3	Lit. cover-overhang veg (Areal Prop)
XGB	3	Rip Ground Layer Barren (Cover)
LSUB_DMM	2	Thalweg sub.-Mean Log10(Diam Class mm)
PCT_SLOW	2	Slow Wtr Hab (% Glide & Pool)
PCT_SNAG	2	Percent of reach with snags
V1TM100	2	LWD vol in/abv wt chan(#/100m-all sizes)
W1_HALL	**2**	**Rip Dist--Sum All Types (ProxWt Pres)**
XCL	2	Riparian Canopy > 0.3m DBH (Cover)
XFC_RCK	**2**	**Littoral fish cvr-boulders (Areal Prop)**
XLIT	2	Mean littoral depth (m)
XPCM	2	Rip Can & MidLayer Present (Frac. reach)
XPCMG	2	Riparian 3-Layers Present (Fract. reach)
V1W_MSQ	1	LWD vol in Bkf chnl&dry(m3/m2-all sizes)
REACHLEN	1	Length of sample reach (m)
SDWXD	1	Std Dev of Width*Depth Product (m2)
VLIT	1	Stdev. littoral depth (m)
W1_HNOAG	1	Rip Dist--Sum NonAg Types (ProxWt Pres)
W1H_WALL	1	Rip Dist--Wall/Bank Revet. (ProxWt Pres)
XC	1	Riparian Veg Canopy Cover
XFC_BRS	1	Lit. cvr-brush&small debris (Areal Prop)
XFC_LWD	1	Littoral cover-LWD (Areal Prop)
XG	1	Riparian Veg Ground Layer Cover
XPMG	1	Riparian mid & gnd Present (Frac. reach)
XPMGH	1	Rip. mid & gnd herb Present (Frac. reach)
XPMGW	1	Rip. mid & gnd wood Present (Frac. reach)
PCT_BH	0	Thal sub. bedrock or hardpan -- >4 m (%)
PCT_FAST	0	Fast Wtr Hab (% riffle & faster)
PCT_FN	0	Thalweg sub. Fines -- Silt/Clay/Muck (%)
PCT_SA	0	Thalweg substrate Sand -- .06-2 mm (%)
PCT_SAFN	0	Thalweg sub. Sand & Fines -- <2 mm (%)
PCT_SIDE	0	Side channel presence (% of reach)
SDDEPTH	0	Std Dev of Thalweg Depth (m)
SINU	0	Channel Sinuosity (m/m)
W1H_PIPE	0	Rip Dist--Pipes infl/effl (ProxWt Pres)
XBKF_W	0	Bankfull Width--Mean (m)
XCDENBK	0	Mean Bank Canopy Density (%)
XCMGW	0	Rip Veg Canopy+Mid+Ground Woody Cover
XCMW	0	Rip Veg Canopy+Mid Layer Woody Cover

XDEPTH	0	Thalweg Mean Depth (m)
XFC_ALL	0	Lit. cover-sum(all) (Areal Prop)
XFC_BIG	0	Lit. cvr-sum(LWD,RCK,UCB,HUM Area Prop)
XFC_HUM	0	Lit. cover-artif. structs. (Areal Prop)
XFC_NAT	0	Lit. cover-sum(nat. types)(Areal Prop)
XFC_UCB	0	Lit. cover-undercut banks (Areal Prop)
XINC_H	0	Channel Incision Ht.-Mean (m)
XWD_RAT	0	Mean Width/Depth Ratio (m/m)
XWIDTH	0	Wetted Width -- Mean (m)
XWXD	0	Mean Width*Depth Product (m2)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PCT_FAST, sensitivity=0
PCT_FN, sensitivity=0
PCT_SA, sensitivity=0
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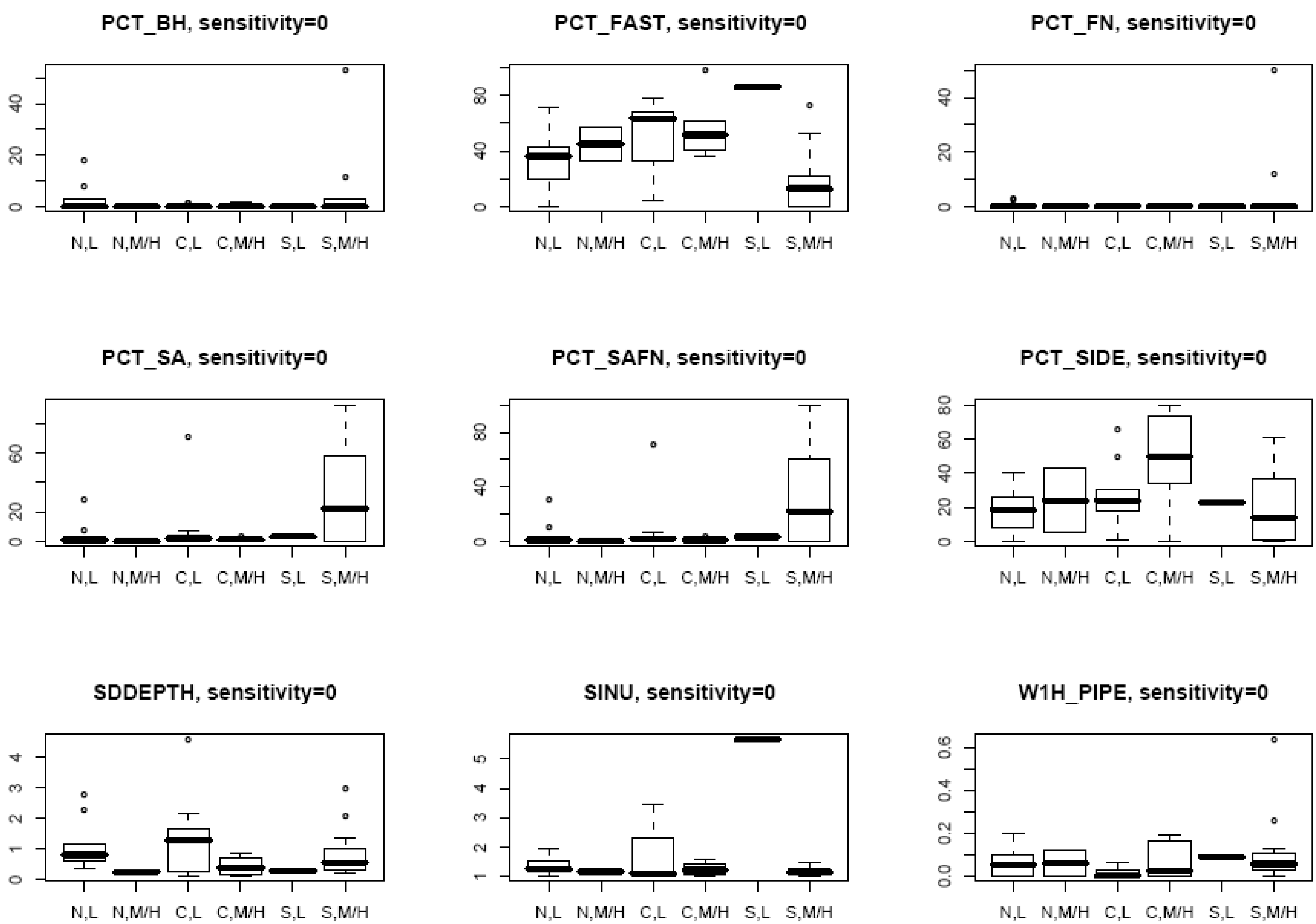
PCT_SIDE, sensitivity=0
SDDEPTH, sensitivity=0
SINU, sensitivity=0
W1H_PIPE, sensitivity=0
L
M/H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PCT_SA, sensitivity=0
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60
PCT_SAFN, sensitivity=0
0
40
80
PCT_SIDE, sensitivity=0
0
20
40
60
80
SDDEPTH, sensitivity=0
0
1
2
3
4
SINU, sensitivity=0
1
2
3
4
5
W1H_PIPE, sensitivity=0
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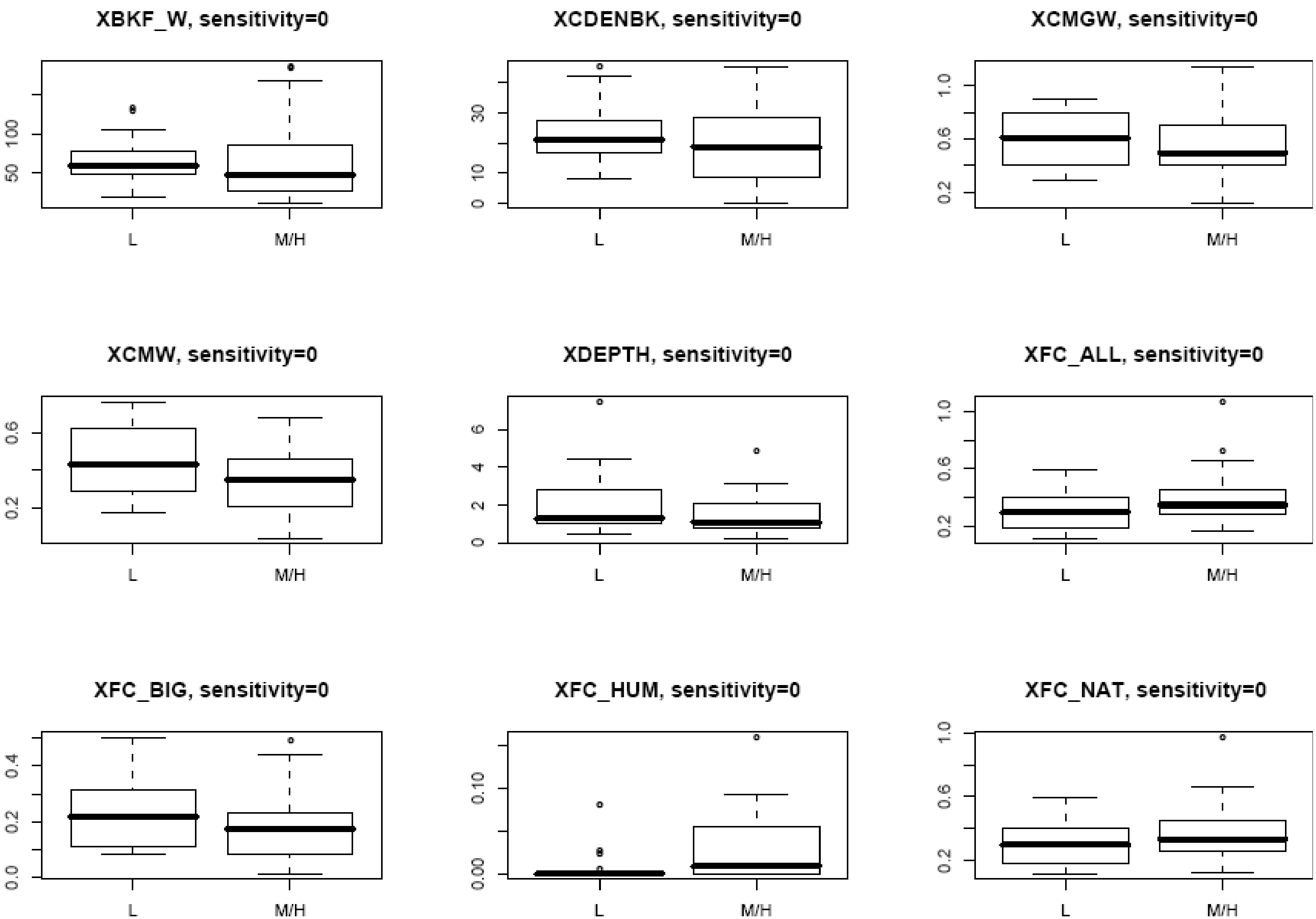
0.2
0.4
0.6
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H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100
L
M/H
XCDENBK, sensitivity=0
0
10
30
L
M/H
XCMGW, sensitivity=0
0.2
0.6
1.0
L
M/H
XCMW, sensitivity=0
0.2
0.6
L
M/H
XDEPTH, sensitivity=0
0
2
4
6
L
M/H
XFC_ALL, sensitivity=0
0.2
0.6
1.0
L
M/H
XFC_BIG, sensitivity=0
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0.2
0.4
L
M/H
XFC_HUM, sensitivity=0
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0.10
L
M/H
XFC_NAT, sensitivity=0
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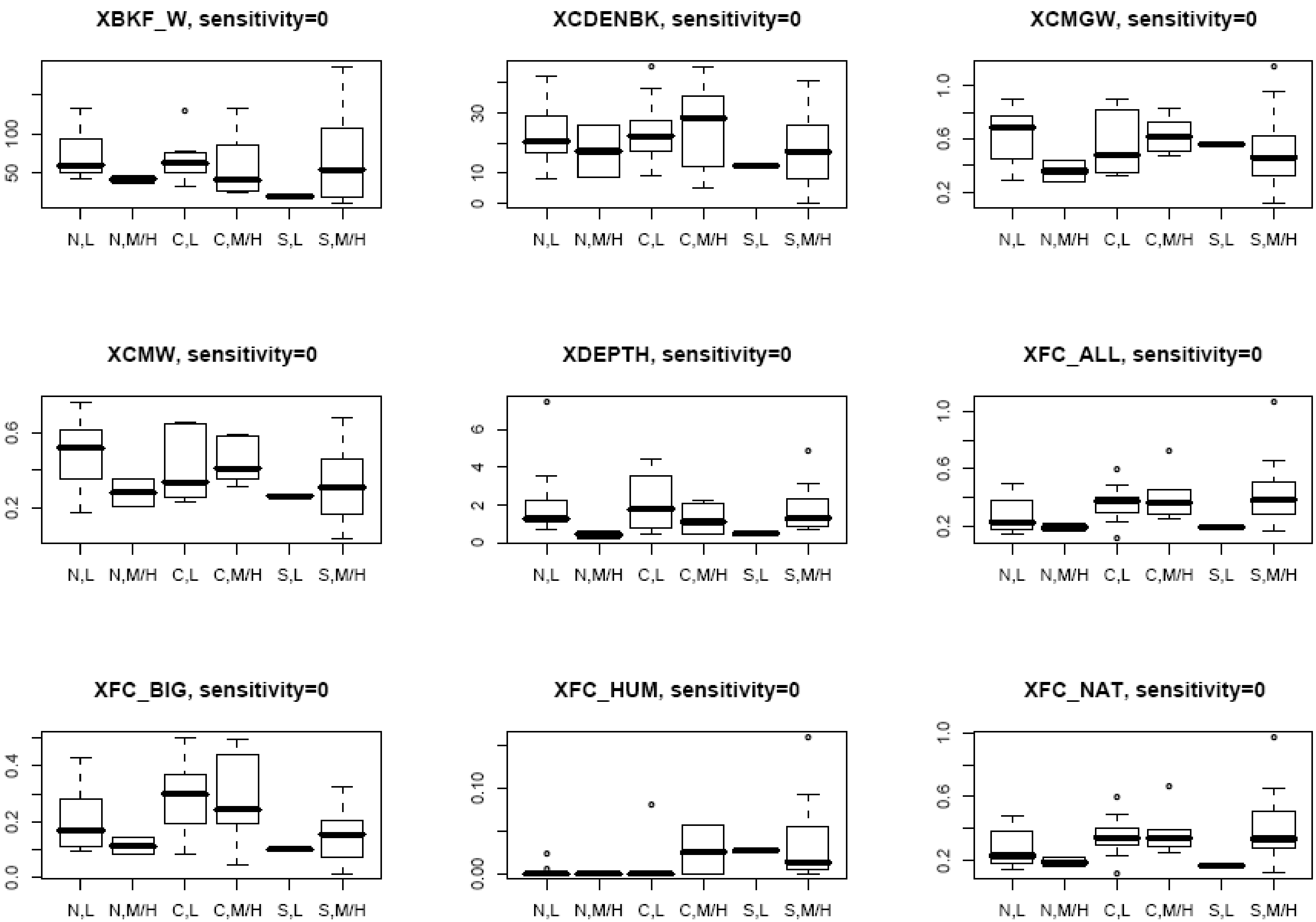
0.6
1.0
L
M/H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XCMGW, sensitivity=0
XCMW, sensitivity=0
XDEPTH, sensitivity=0
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XFC_BIG, sensitivity=0
XFC_HUM, sensitivity=0
XFC_NAT, sensitivity=0
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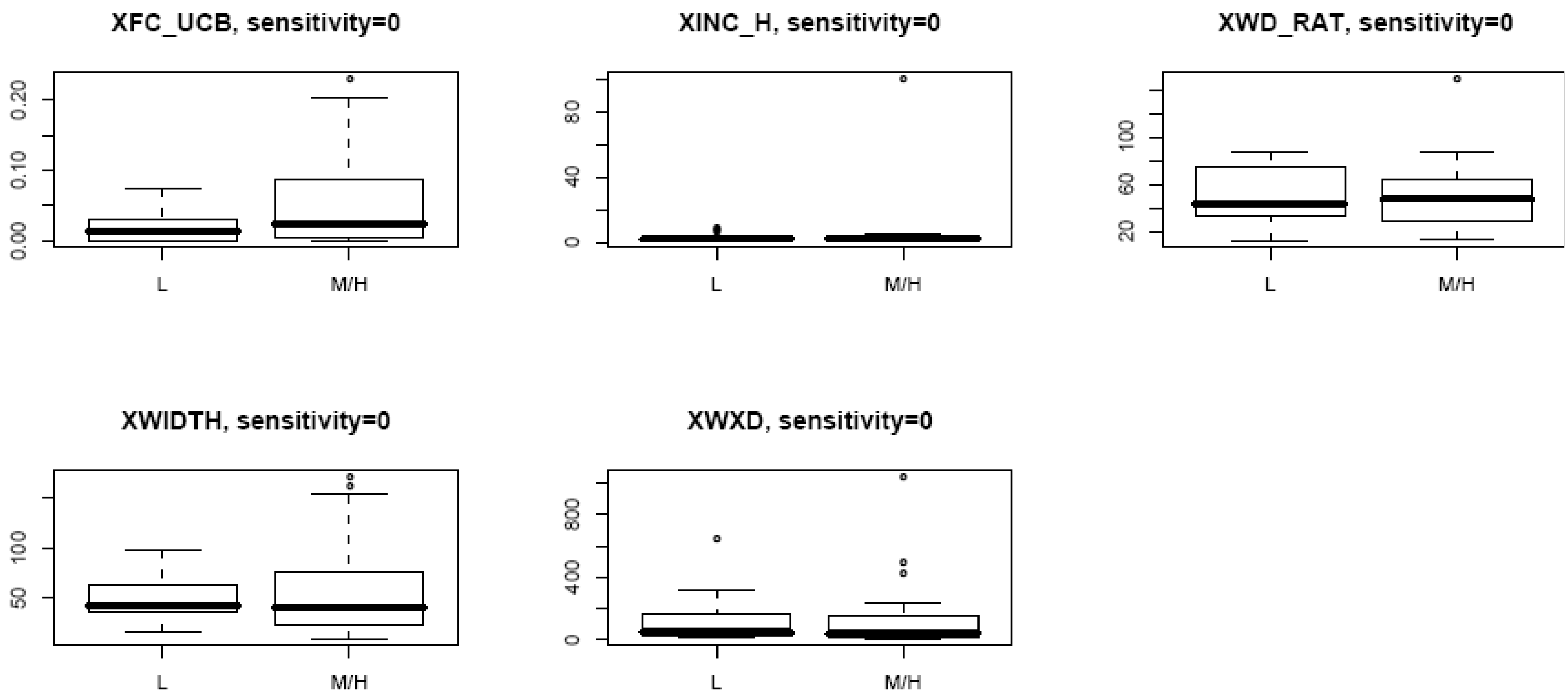
N,M/H
C,L
C,M/H
S,L
S,M/H



XFC_UCB, sensitivity=0
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0.20
L
M/H
XINC_H, sensitivity=0
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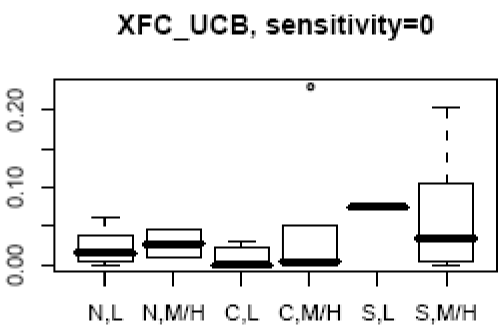
40
80
L
M/H
XWD_RAT, sensitivity=0
20
60
100
L
M/H
XWIDTH, sensitivity=0
50
100
L
M/H
XWXD, sensitivity=0
0
400
800
L
M/H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0.20
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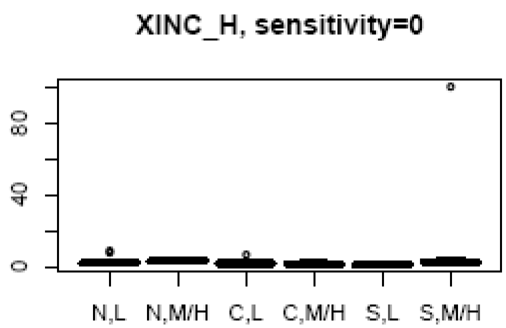
N,M/H
C,L
C,M/H
S,L
S,M/H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40
80
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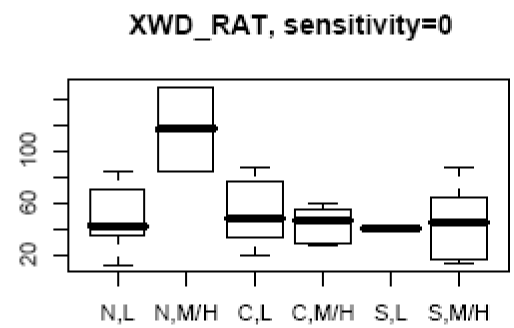
N,M/H
C,L
C,M/H
S,L
S,M/H


XWD_RAT, sensitivity=0
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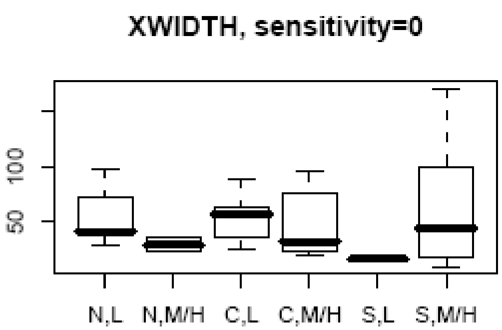
60
100
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


XWIDTH, sensitivity=0
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100
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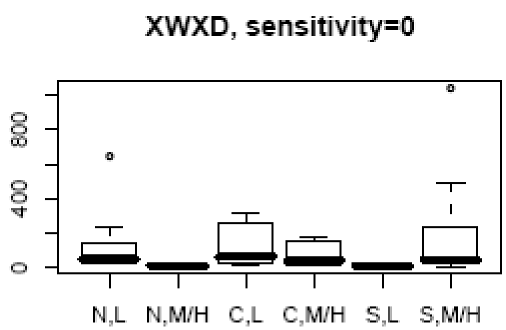
N,M/H
C,L
C,M/H
S,L
S,M/H


XWXD, sensitivity=0
0
400
800
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

E. GIS Metric Sensitivity

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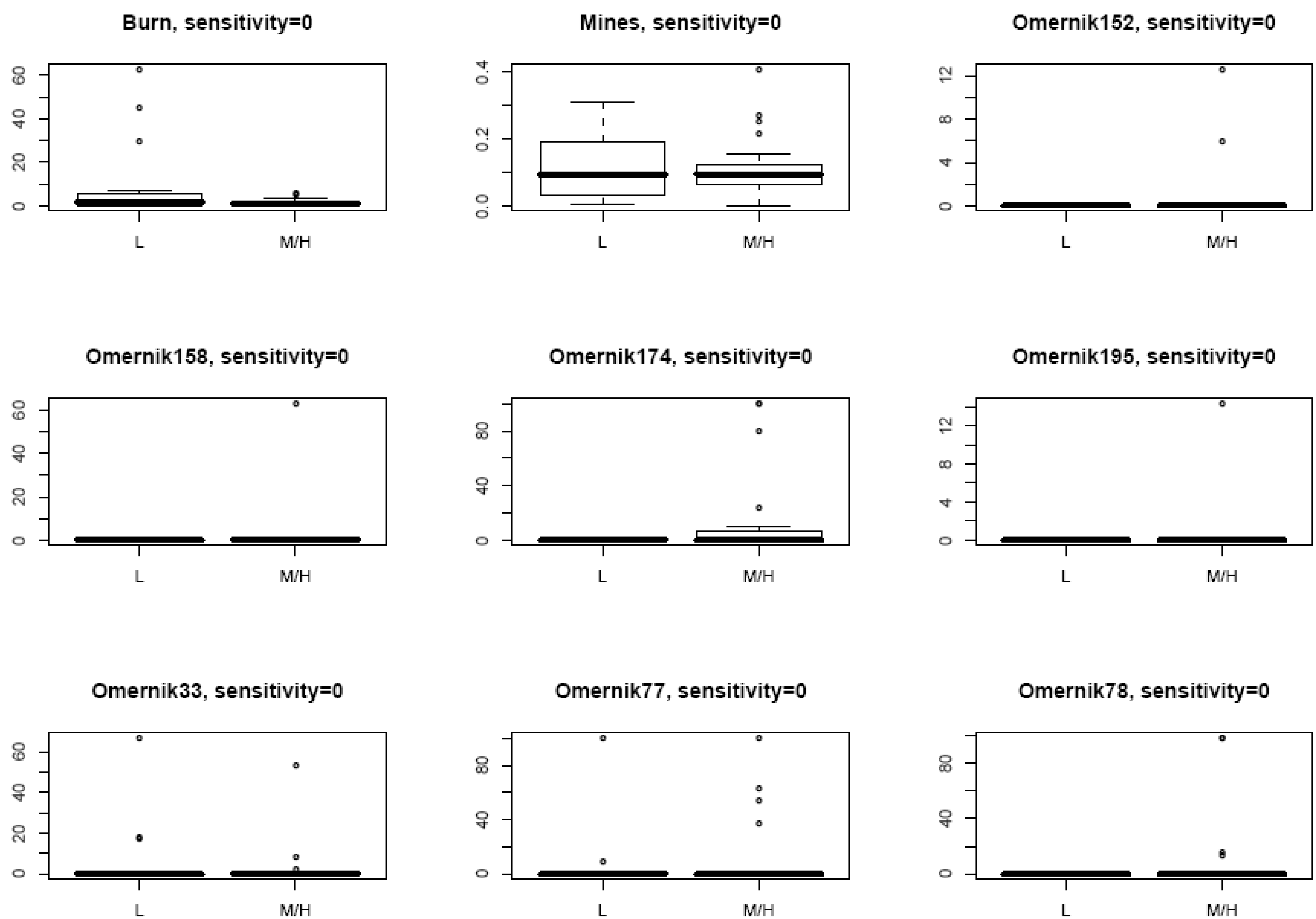
Burn, sensitivity=0
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40
60
L
M/H
Mines, sensitivity=0
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0.2
0.4
L
M/H
Omernik152, sensitivity=0
0
4
8
12
L
M/H
Omernik158, sensitivity=0
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20
40
60
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M/H
Omernik174, sensitivity=0
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40
80
L
M/H
Omernik195, sensitivity=0
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4
8
12
L
M/H
Omernik33, sensitivity=0
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20
40
60
L
M/H
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40
80
L
M/H
Omernik78, sensitivity=0
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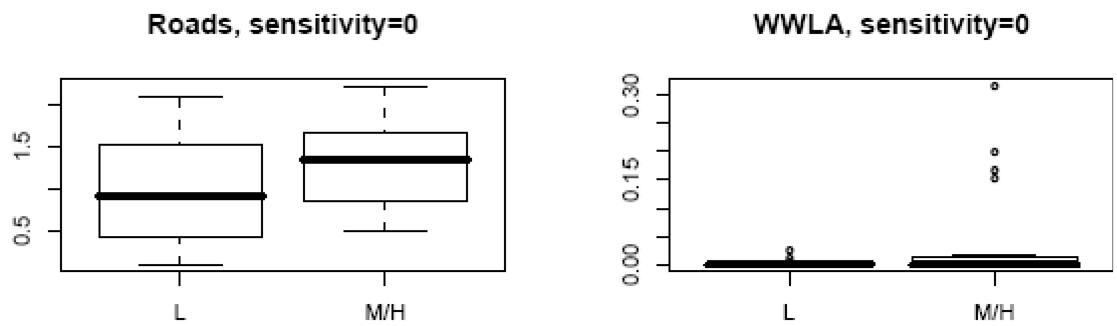
40
80
L
M/H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1.5
L
M/H
WWLA, sensitivity=0
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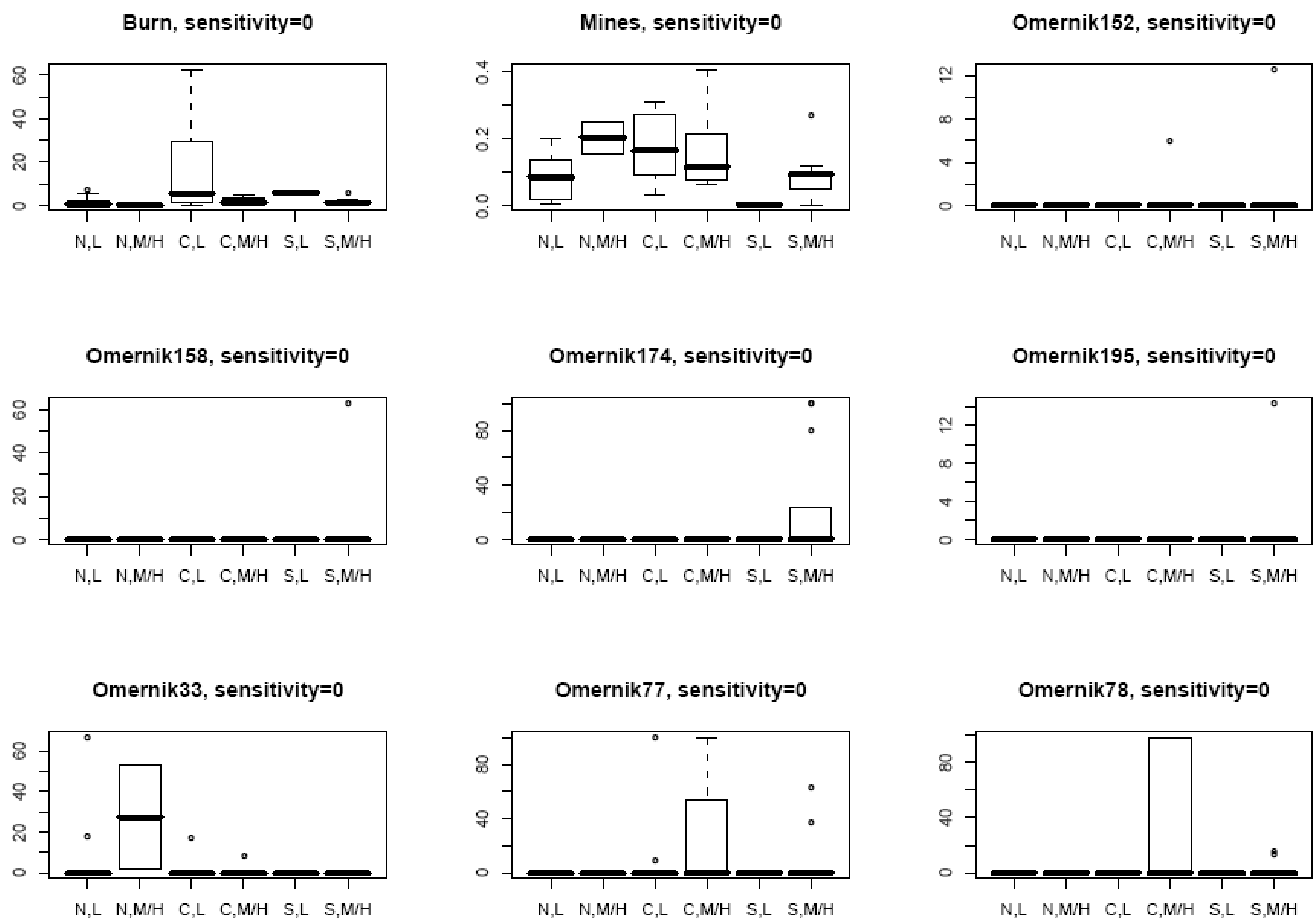
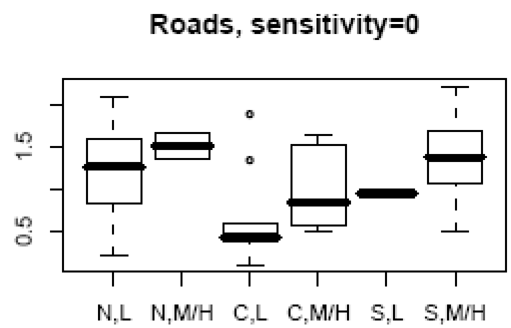
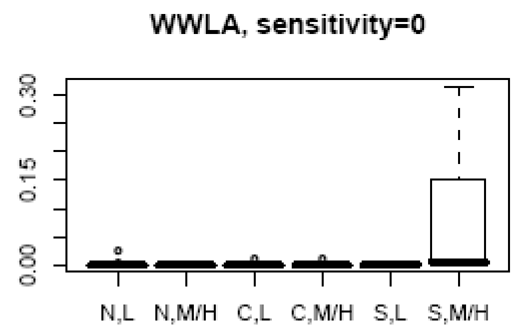
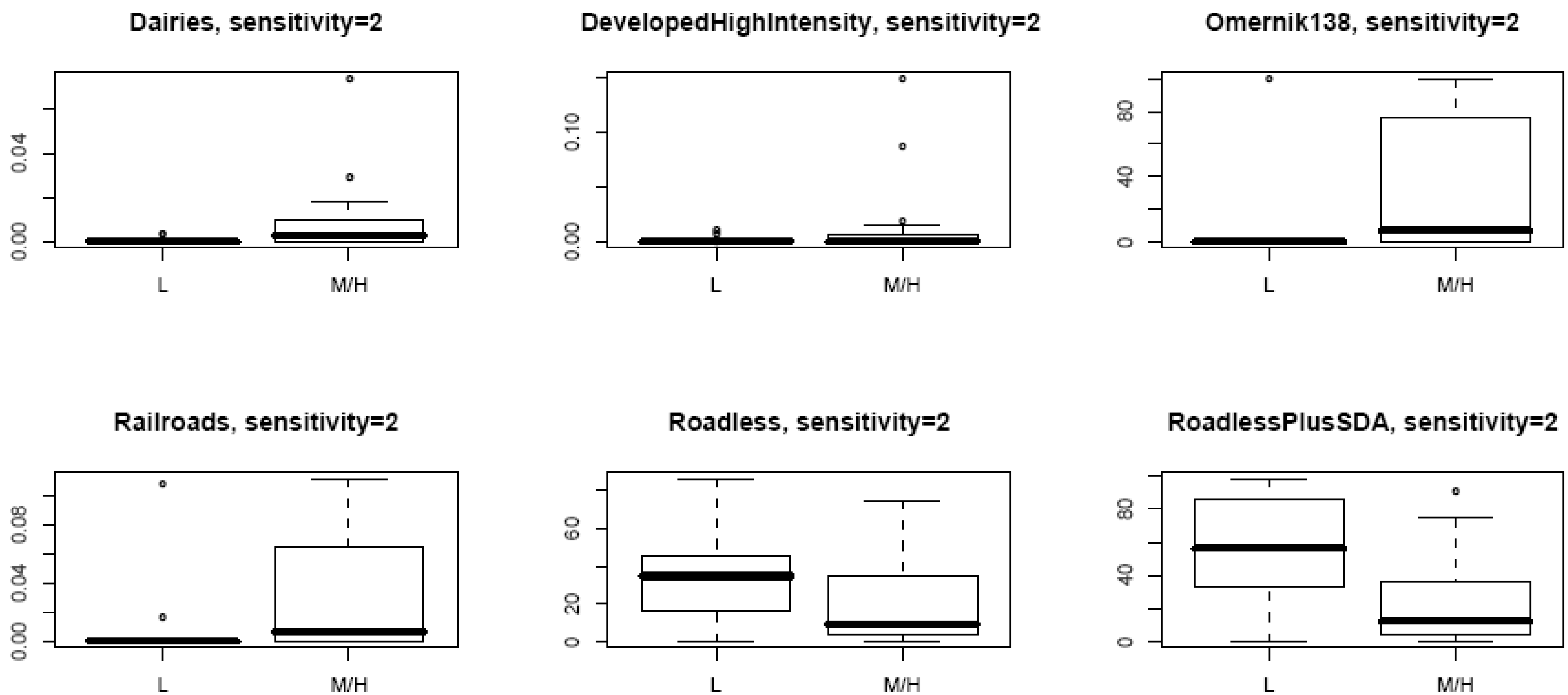
0.15
0.30
L
M/H


Burn, sensitivity=0
Mines, sensitivity=0
Omernik152, sensitivity=0
Omernik158, sensitivity=0
Omernik174, sensitivity=0
Omernik195, sensitivity=0
Omernik33, sensitivity=0
Omernik77, sensitivity=0
Omernik78, sensitivity=0
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


Roads, sensitivity=0
0.5
1.5
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


WWLA, sensitivity=0
0.00
0.15
0.30
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


Dairies, sensitivity=2
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0.04
L
M/H
DevelopedHighIntensity, sensitivity=2
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0.10
L
M/H
Omernik138, sensitivity=2
0
40
80
L
M/H
Railroads, sensitivity=2
0.00
0.04
0.08
L
M/H
Roadless, sensitivity=2
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20
60
L
M/H
RoadlessPlusSDA, sensitivity=2
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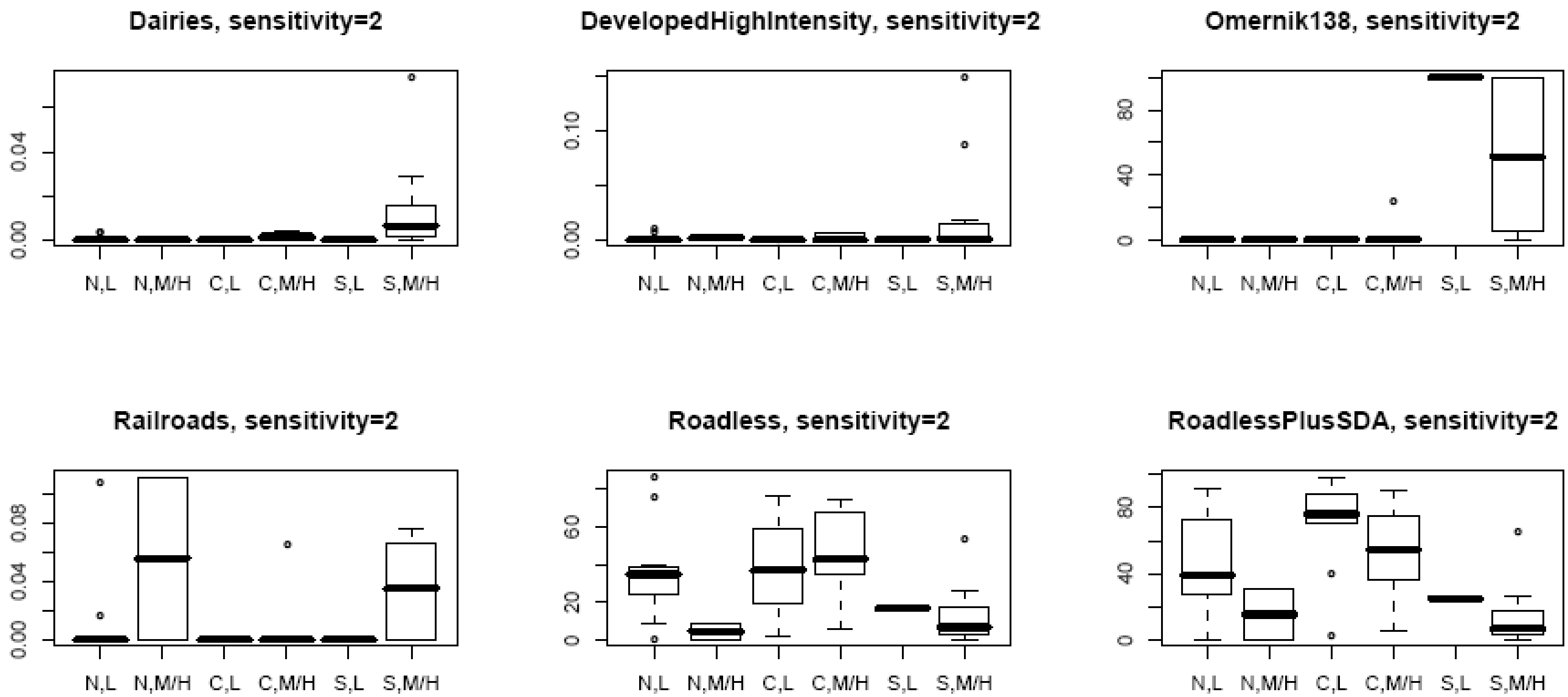
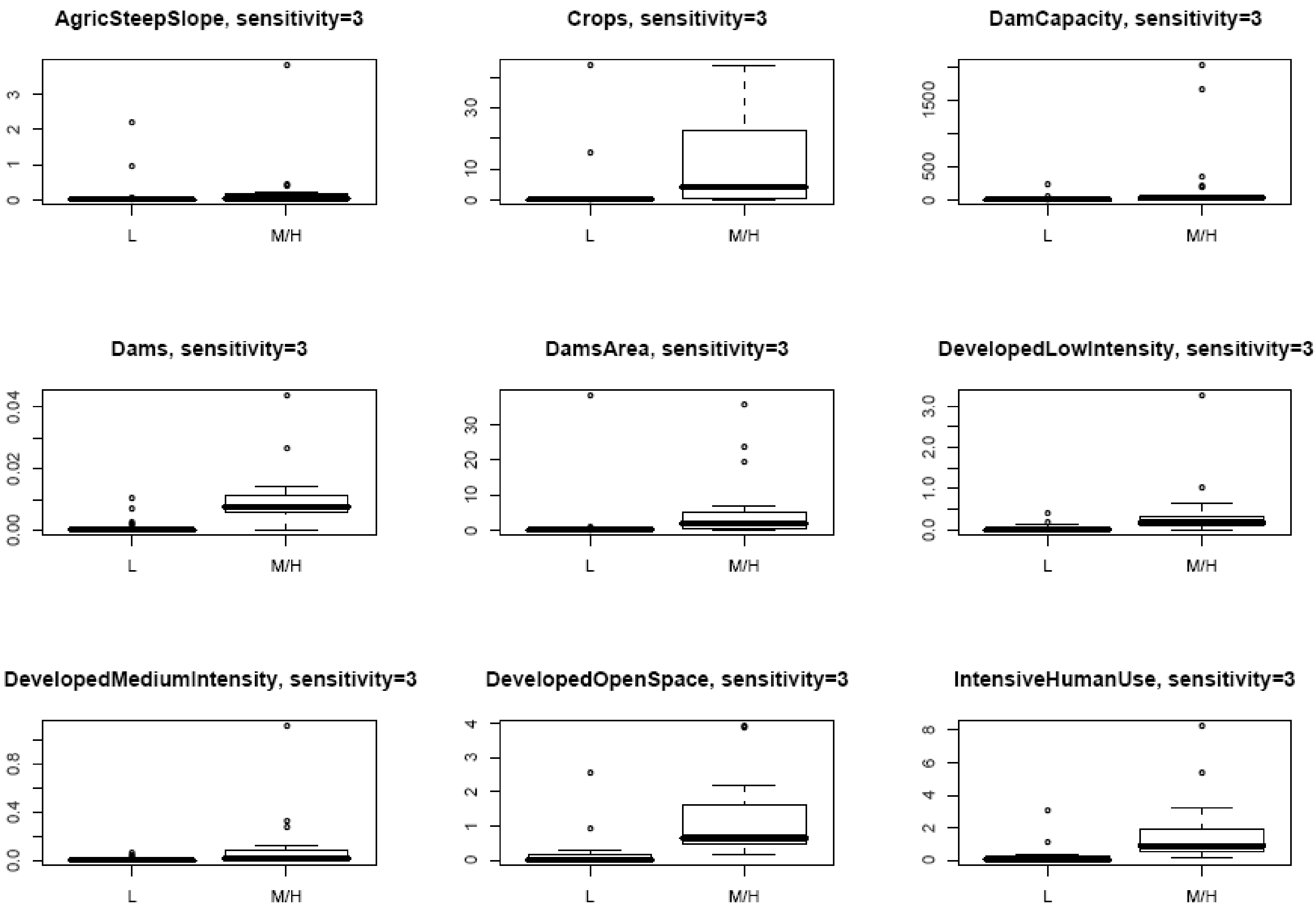
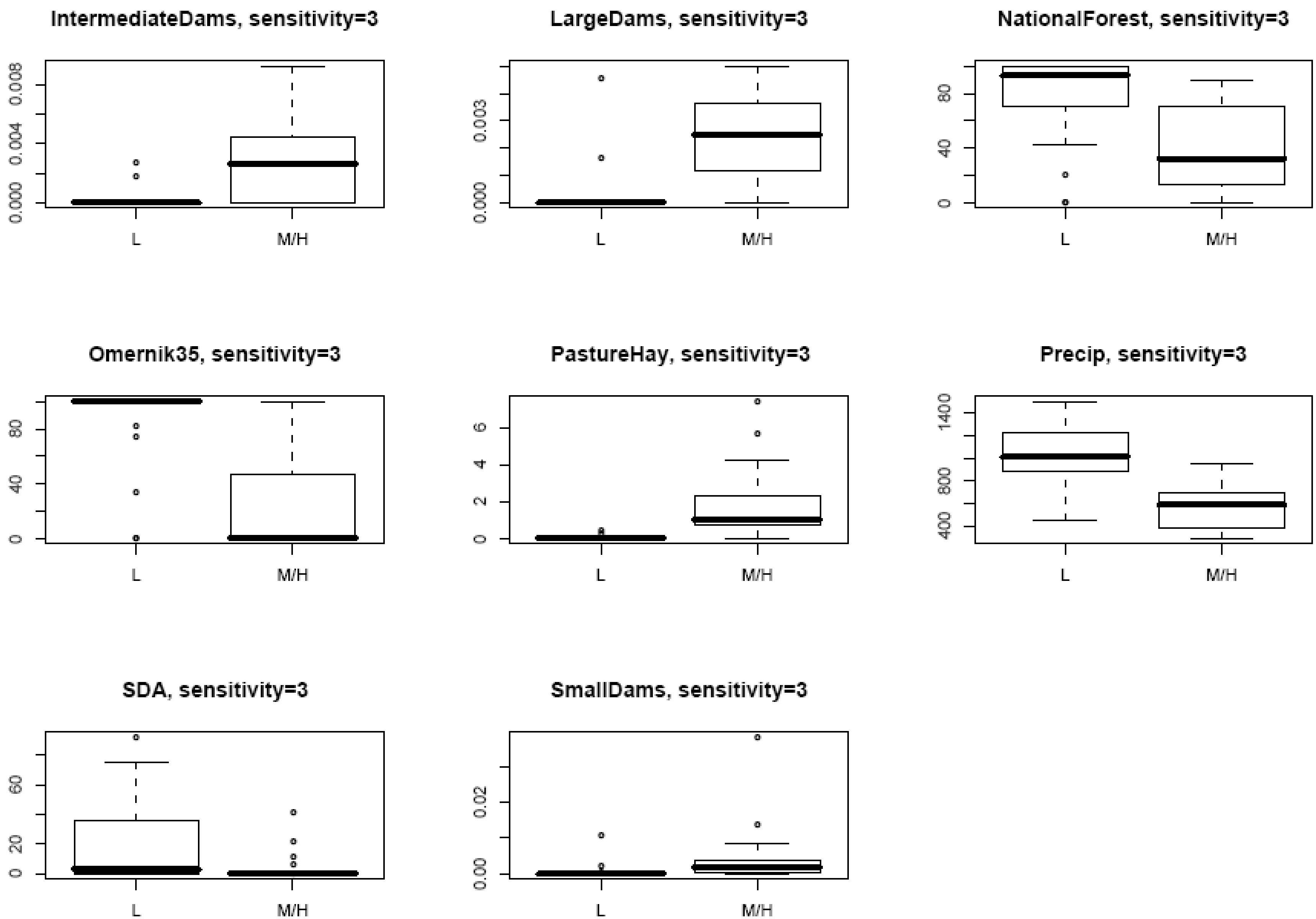
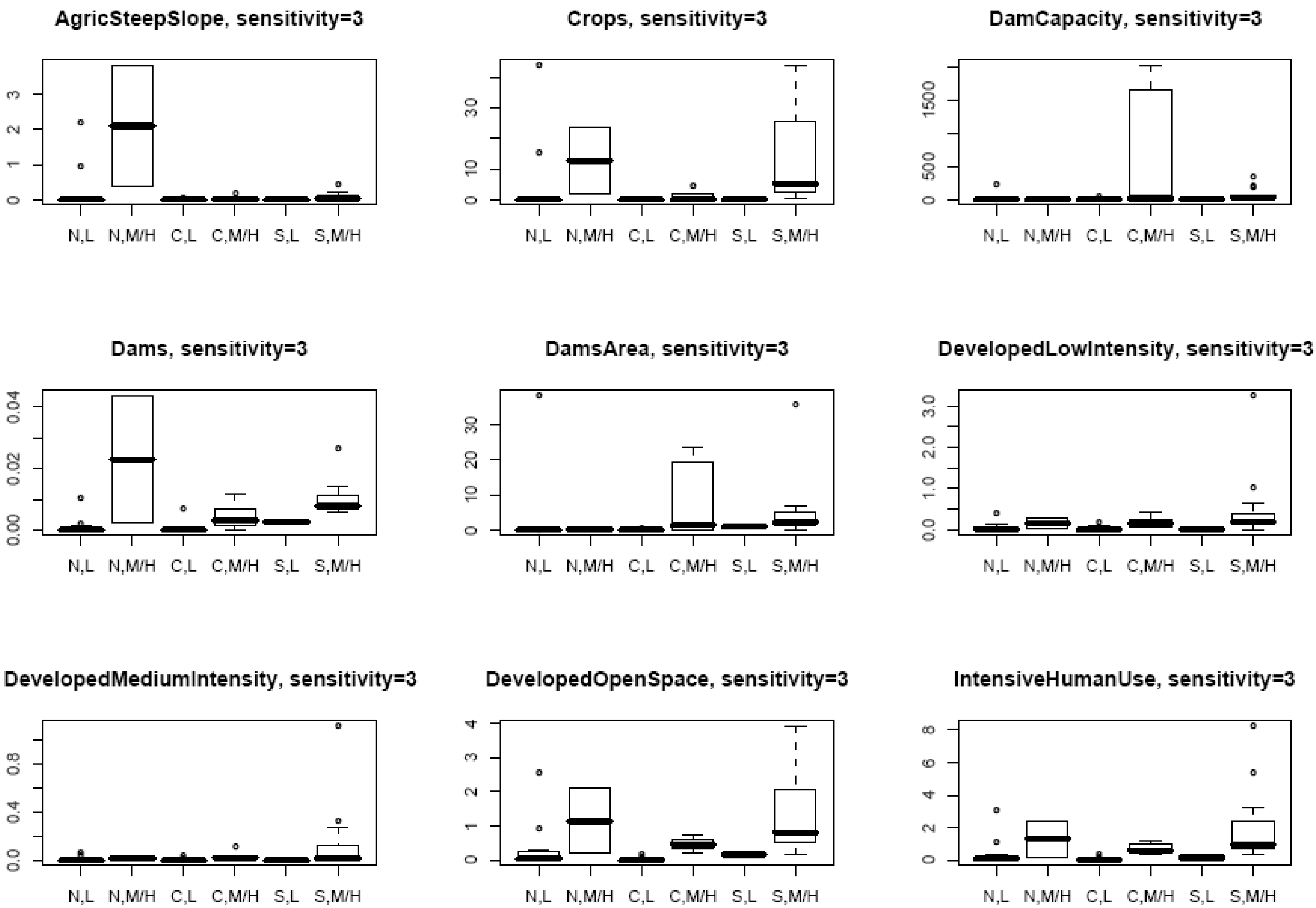
40
80
L
M/H

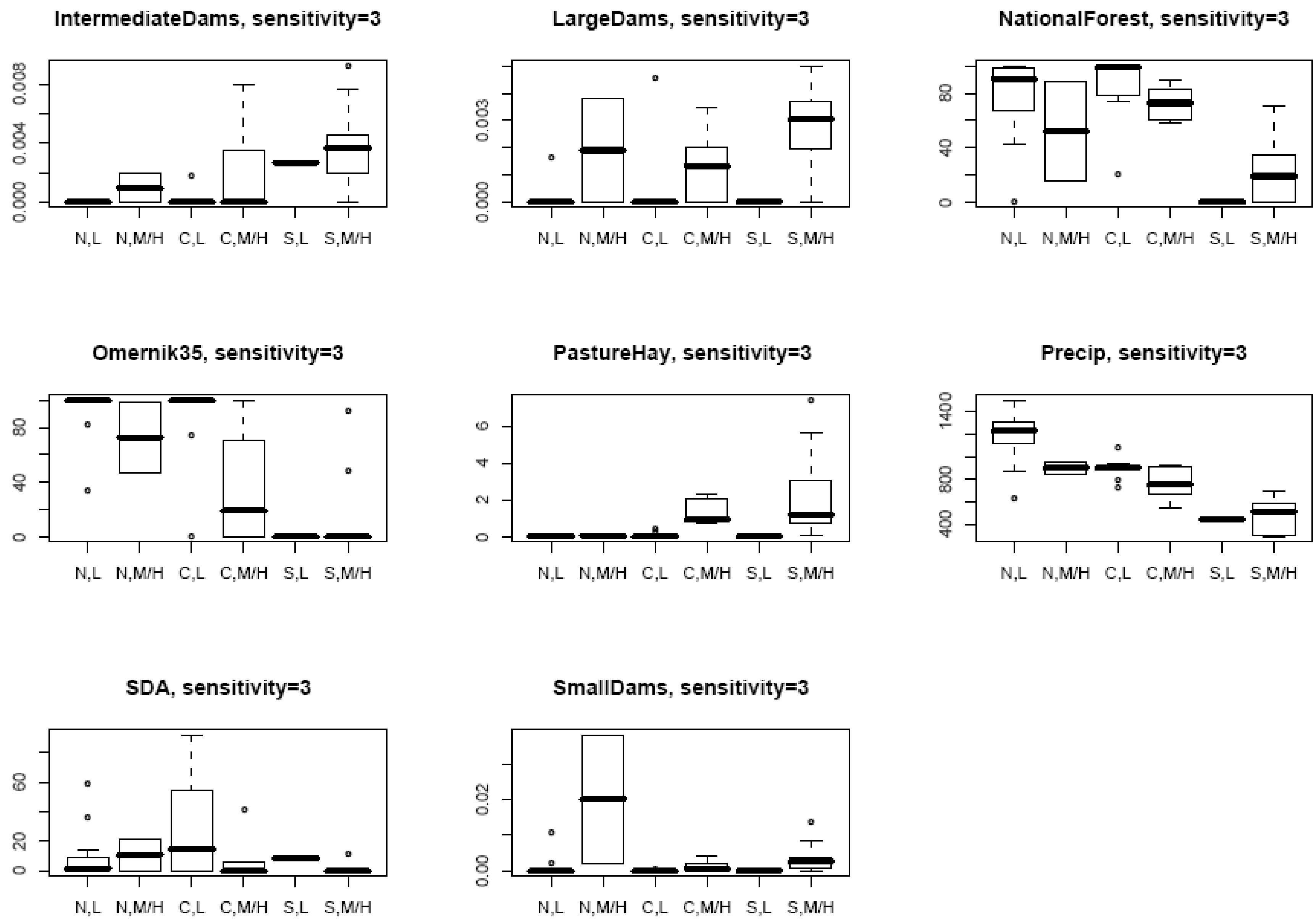


Dairies, sensitivity=2
0.00
0.04
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DevelopedHighIntensity, sensitivity=2
0.00
0.10
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
Omernik138, sensitivity=2
0
40
80
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
Railroads, sensitivity=2
0.00
0.04
0.08
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
Roadless, sensitivity=2
0
20
60
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
RoadlessPlusSDA, sensitivity=2
0
40
80
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


AgricSteepSlope, sensitivity=3
0
1
2
3
L
M/H
Crops, sensitivity=3
0
10
30
L
M/H
DamCapacity, sensitivity=3
0
500
1500
L
M/H
Dams, sensitivity=3
0.00
0.02
0.04
L
M/H
DamsArea, sensitivity=3
0
10
20
30
L
M/H
DevelopedLowIntensity, sensitivity=3
0.0
1.0
2.0
3.0
L
M/H
DevelopedMediumIntensity, sensitivity=3
0.0
0.4
0.8
L
M/H
DevelopedOpenSpace, sensitivity=3
0
1
2
3
4
L
M/H
IntensiveHumanUse, sensitivity=3
0
2
4
6
8
L
M/H


IntermediateDams, sensitivity=3
0.000
0.004
0.008
LargeDams, sensitivity=3
0.000
0.003
NationalForest, sensitivity=3
0
40
80
Omernik35, sensitivity=3
0
40
80
PastureHay, sensitivity=3
0
2
4
6
Precip, sensitivity=3
400
800
1400
SDA, sensitivity=3
0
20
60
SmallDams, sensitivity=3
0.00
0.02
L
M/H


AgricSteepSlope, sensitivity=3
0
1
2
3
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
Crops, sensitivity=3
0
10
30
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DamCapacity, sensitivity=3
0
500
1500
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
Dams, sensitivity=3
0.00
0.02
0.04
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DamsArea, sensitivity=3
0
10
20
30
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DevelopedLowIntensity, sensitivity=3
0.0
1.0
2.0
3.0
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DevelopedMediumIntensity, sensitivity=3
0.0
0.4
0.8
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DevelopedOpenSpace, sensitivity=3
0
1
2
3
4
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
IntensiveHumanUse, sensitivity=3
0
2
4
6
8
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


IntermediateDams, sensitivity=3
LargeDams, sensitivity=3
NationalForest, sensitivity=3
Omernik35, sensitivity=3
PastureHay, sensitivity=3
Precip, sensitivity=3
SDA, sensitivity=3
SmallDams, sensitivity=3
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

F. Chemical Metric Sensitivity

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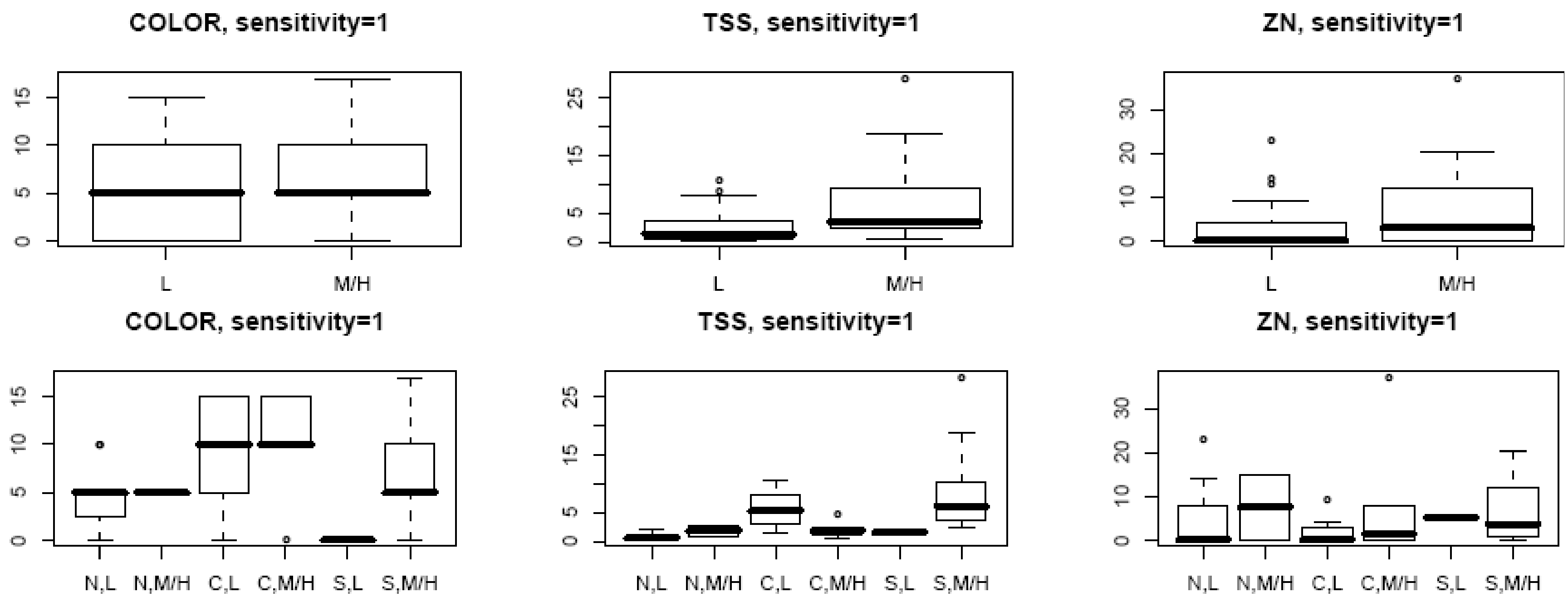
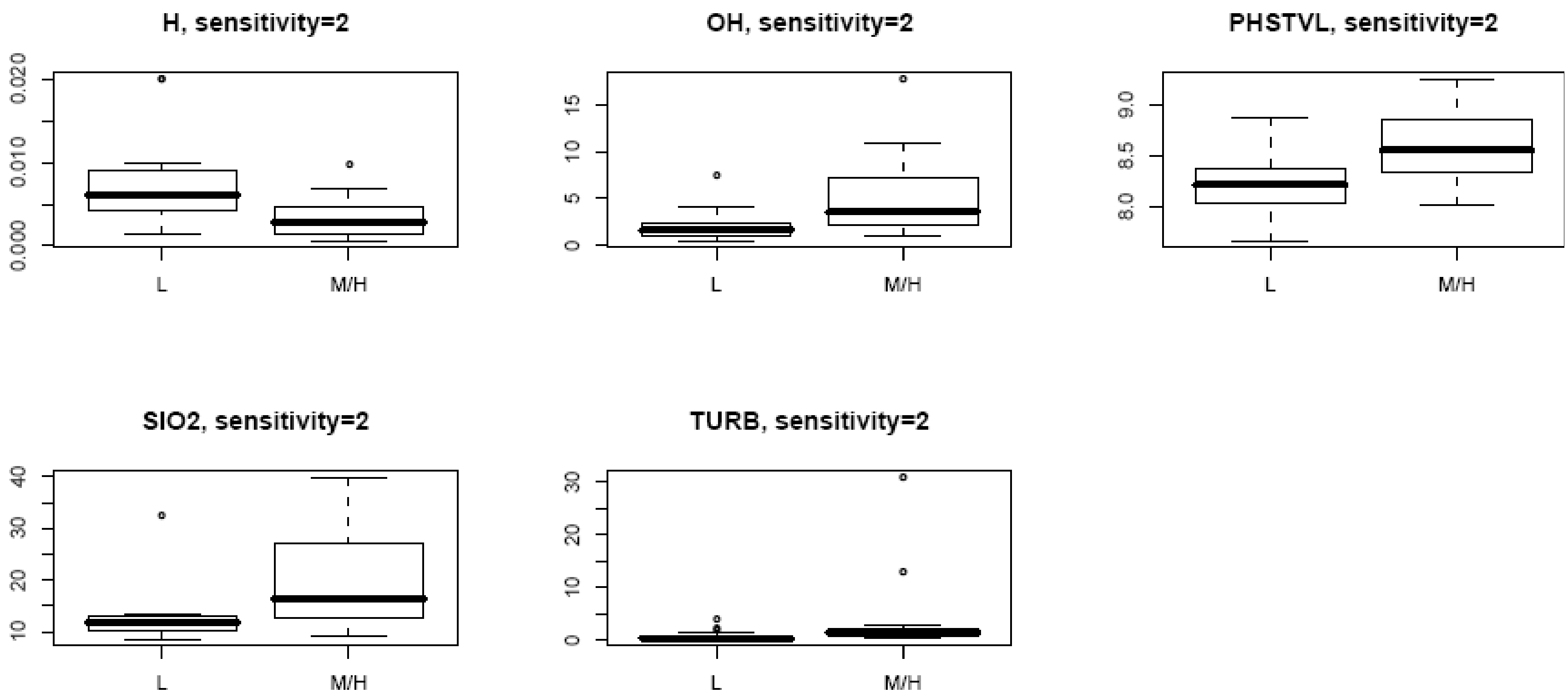
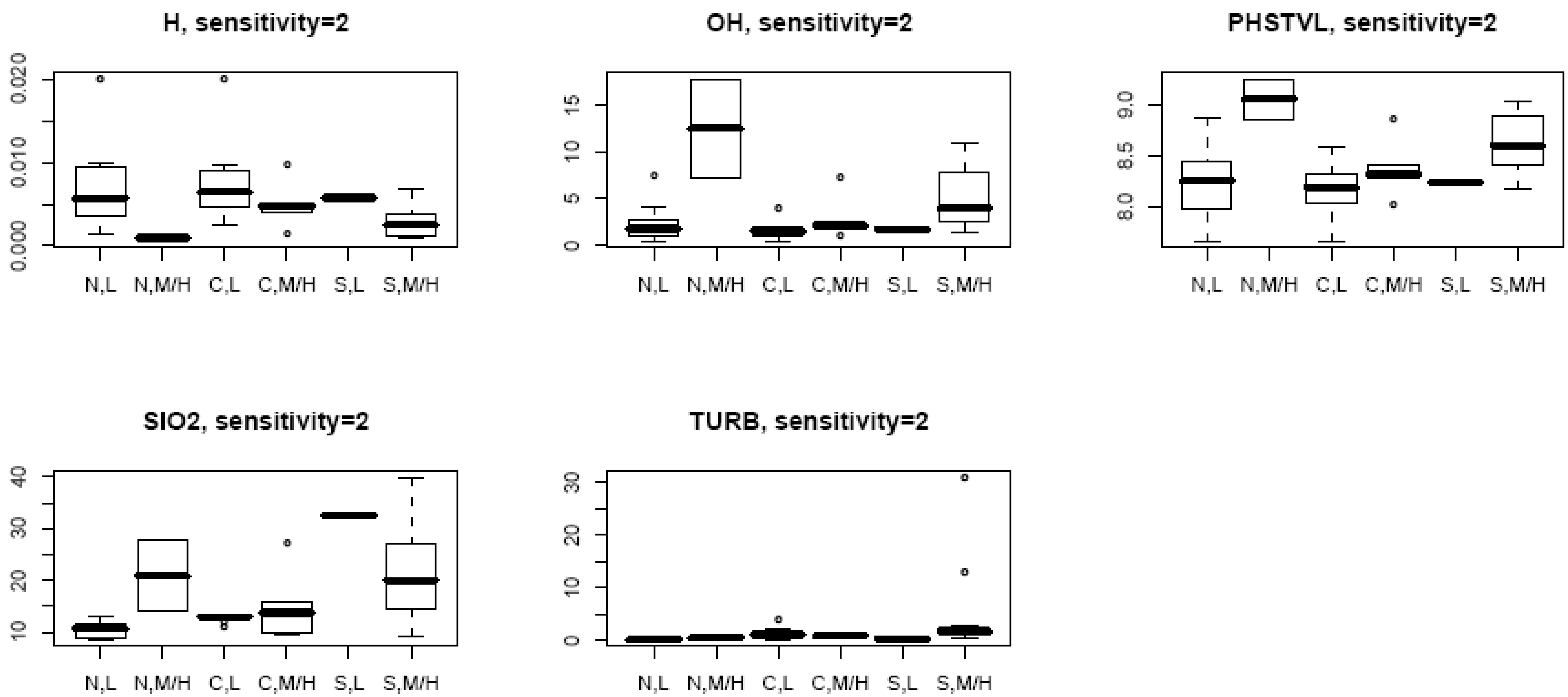
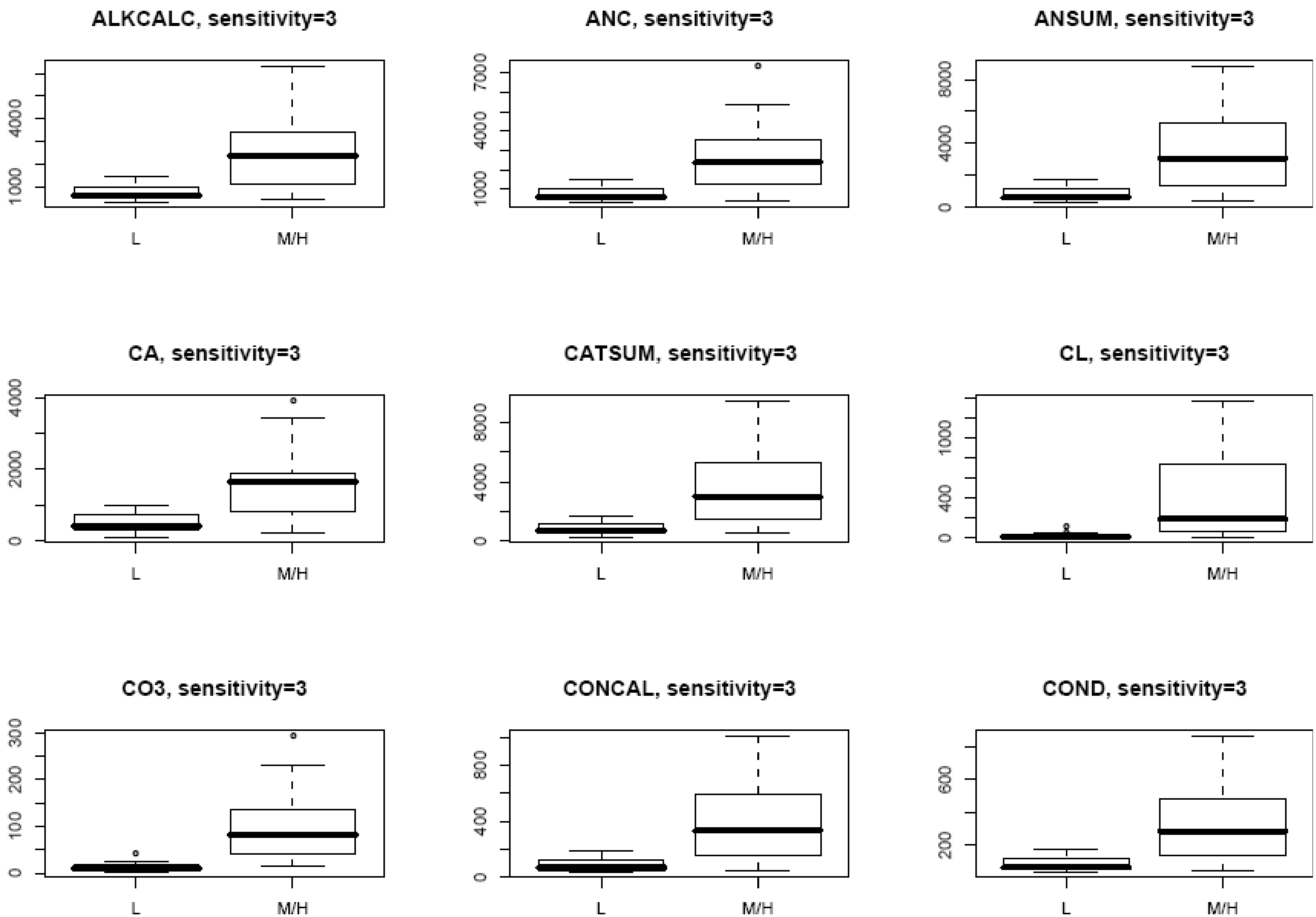
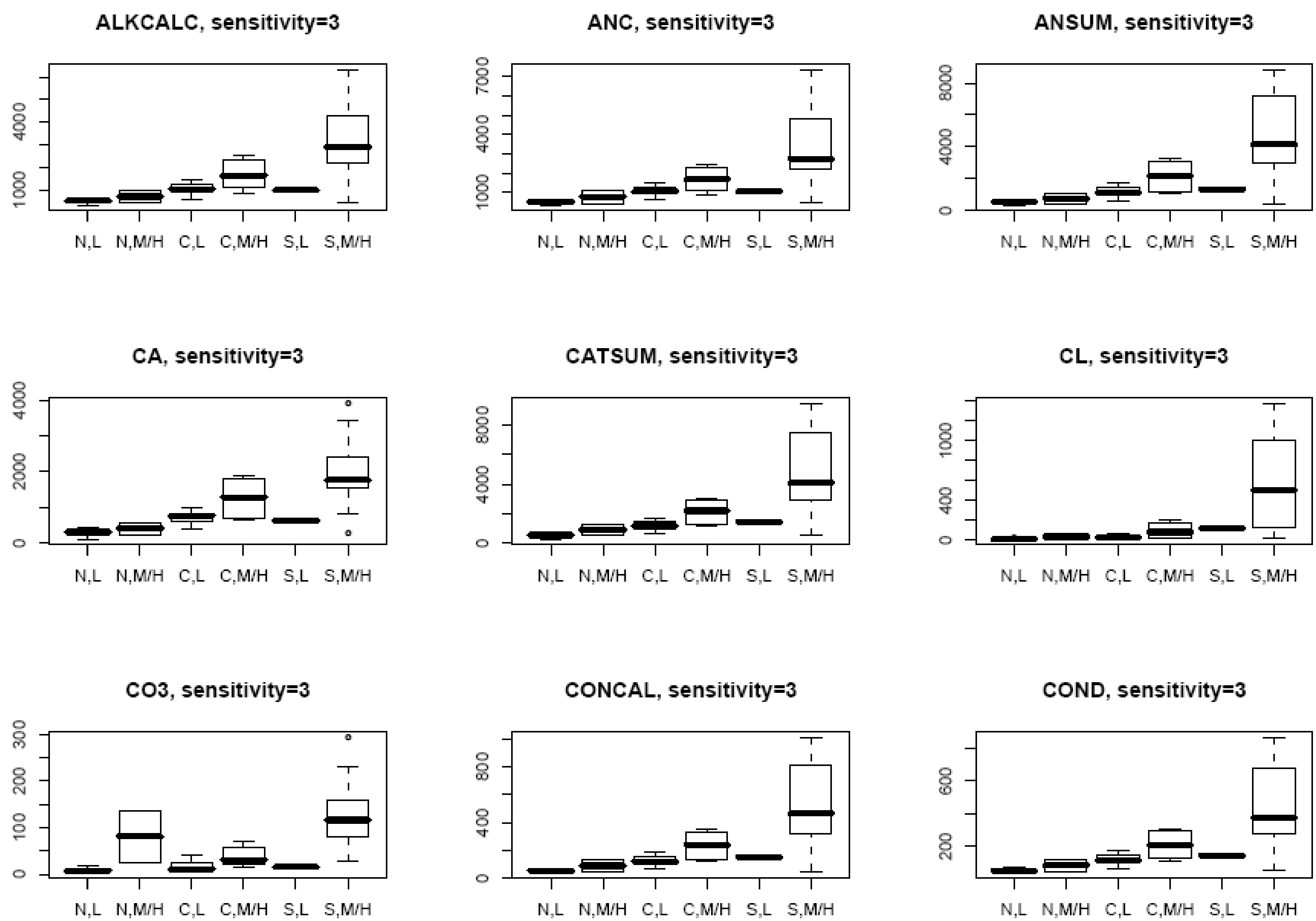

COLOR, sensitivity=1
TSS, sensitivity=1
ZN, sensitivity=1
L
M/H
COLOR, sensitivity=1
TSS, sensitivity=1
ZN, sensitivity=1
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

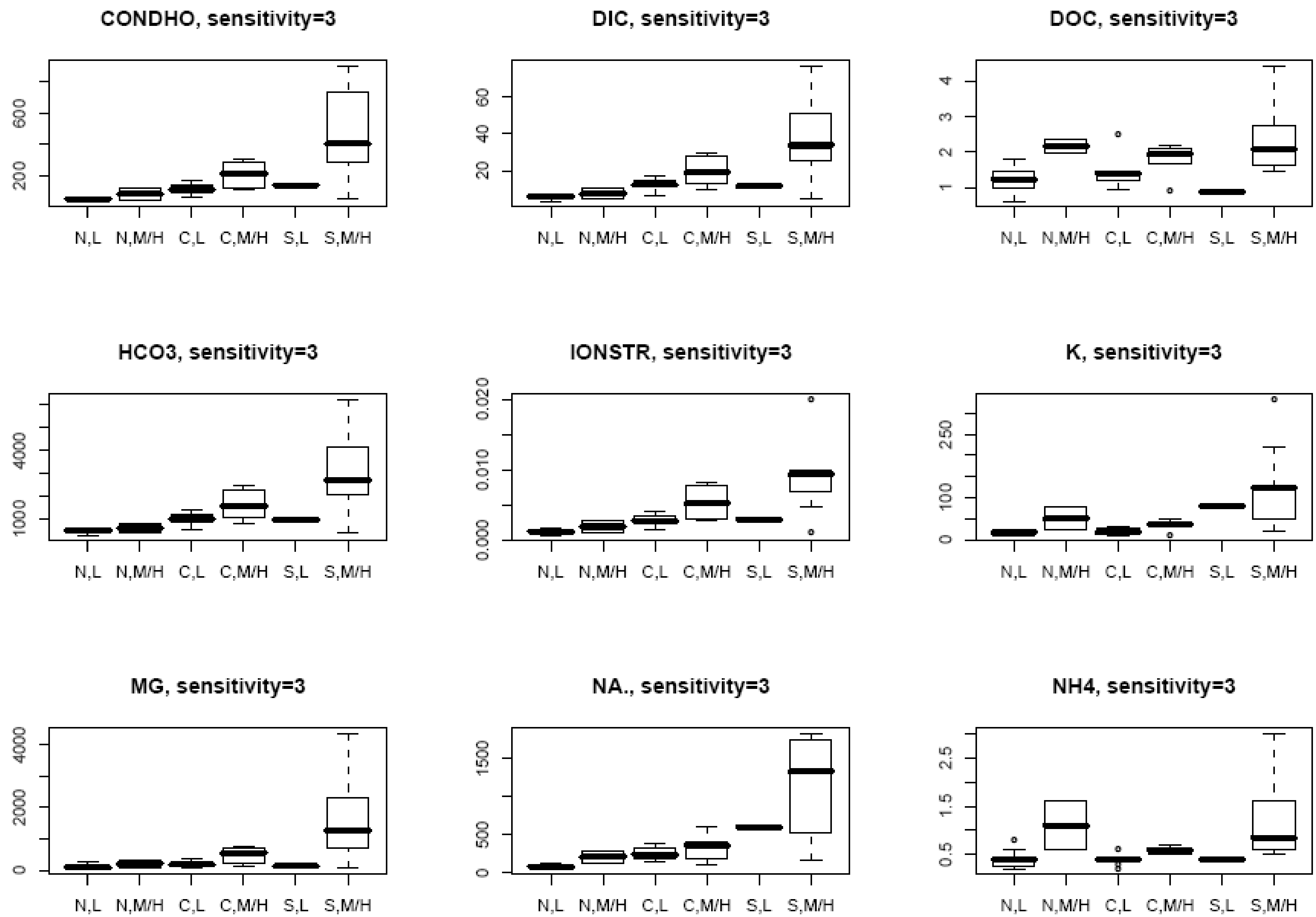

H, sensitivity=2
0.000
0.010
0.020
L
M/H
OH, sensitivity=2
0
5
10
15
L
M/H
PHSTVL, sensitivity=2
8.0
8.5
9.0
L
M/H
SIO2, sensitivity=2
10
20
30
40
L
M/H
TURB, sensitivity=2
0
10
20
30
L
M/H

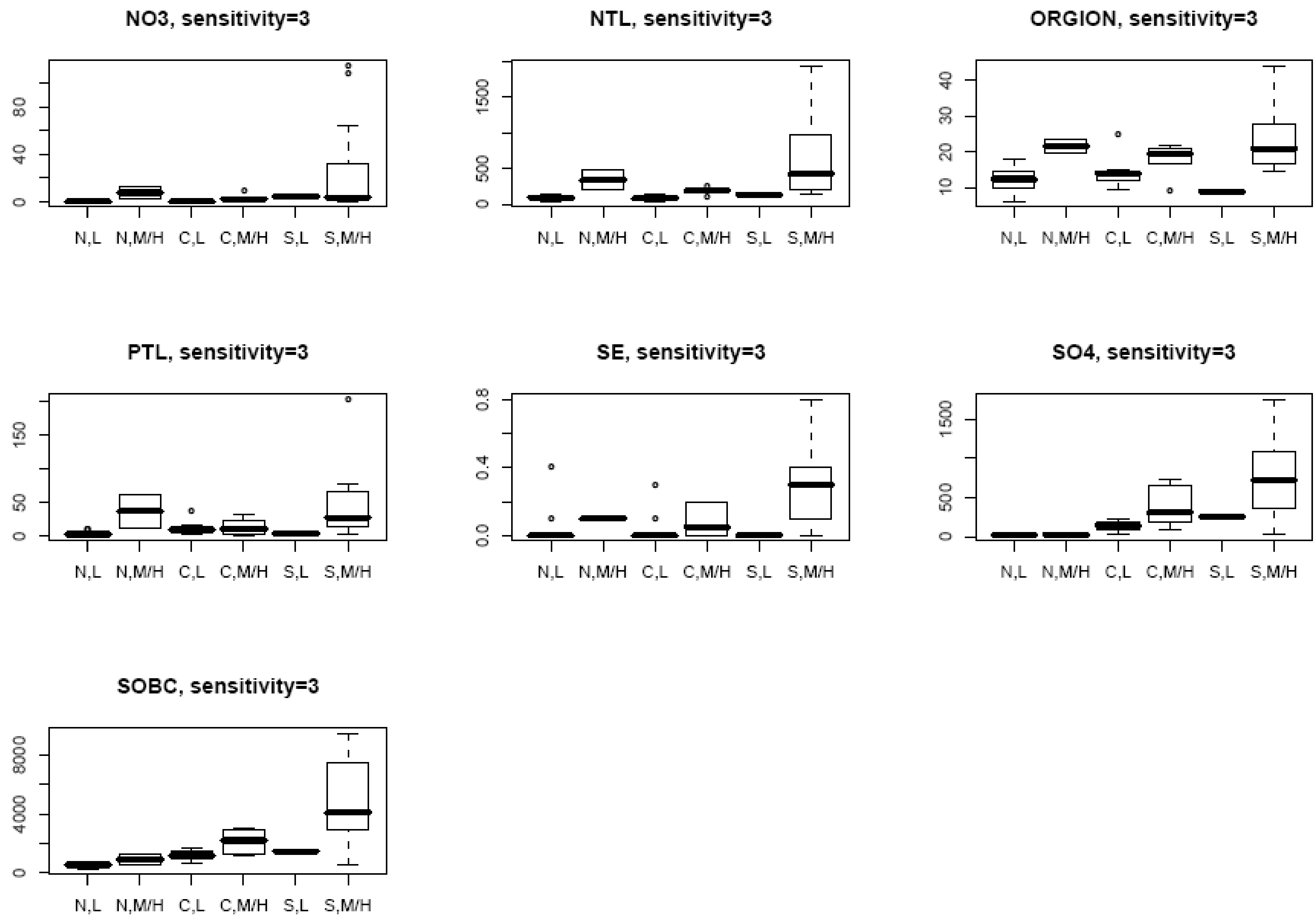

H, sensitivity=2
0.000
0.010
0.020
OH, sensitivity=2
0
5
10
15
PHSTVL, sensitivity=2
8.0
8.5
9.0
SIO2, sensitivity=2
10
20
30
40
TURB, sensitivity=2
0
10
20
30
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H



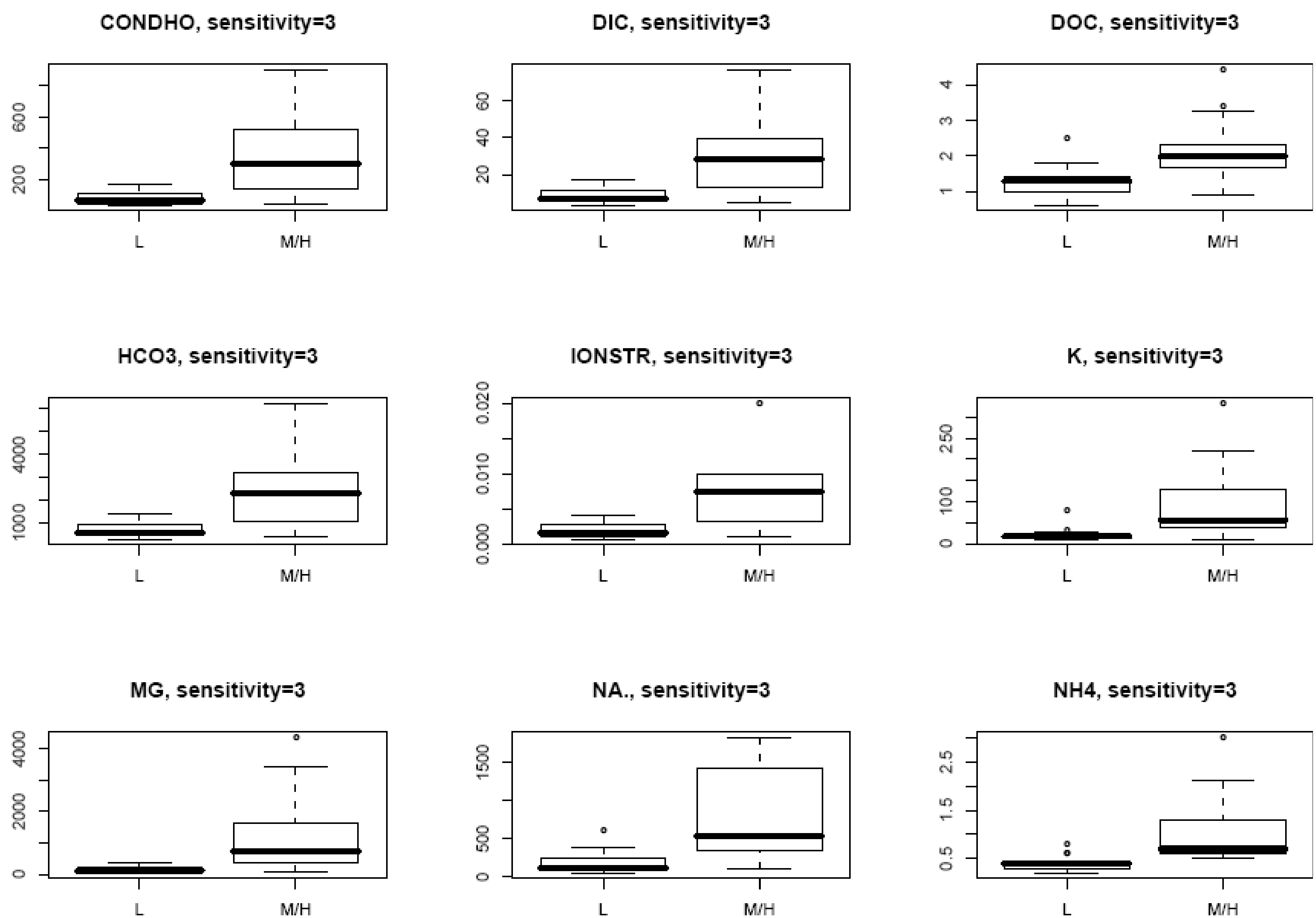
ALKCALC, sensitivity=3
1000
4000
L
M/H
ANC, sensitivity=3
1000
4000
7000
L
M/H
ANSUM, sensitivity=3
0
4000
8000
L
M/H
CA, sensitivity=3
0
2000
4000
L
M/H
CATSUM, sensitivity=3
0
4000
8000
L
M/H
CL, sensitivity=3
0
400
1000
L
M/H
CO3, sensitivity=3
0
100
200
300
L
M/H
CONCAL, sensitivity=3
0
400
800
L
M/H
COND, sensitivity=3
200
600
L
M/H

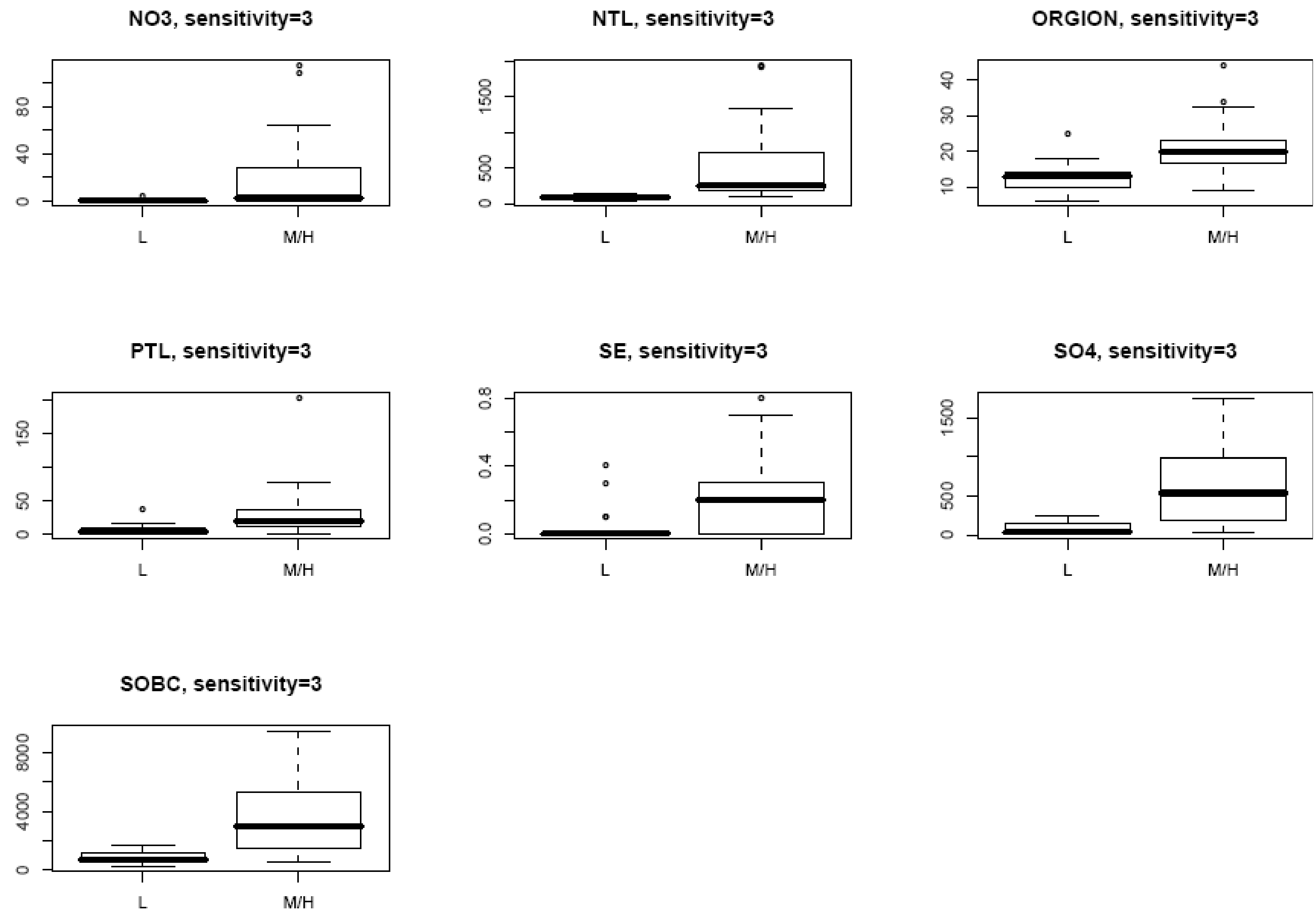

ALKCALC, sensitivity=3
1000
4000
N,L N,M/H C,L C,M/H S,L S,M/H
ANC, sensitivity=3
1000
4000
7000
N,L N,M/H C,L C,M/H S,L S,M/H
ANSUM, sensitivity=3
0
4000
8000
N,L N,M/H C,L C,M/H S,L S,M/H
CA, sensitivity=3
0
2000
4000
N,L N,M/H C,L C,M/H S,L S,M/H
CATSUM, sensitivity=3
0
4000
8000
N,L N,M/H C,L C,M/H S,L S,M/H
CL, sensitivity=3
0
400
1000
N,L N,M/H C,L C,M/H S,L S,M/H
CO3, sensitivity=3
0
100
200
300
N,L N,M/H C,L C,M/H S,L S,M/H
CONCAL, sensitivity=3
0
400
800
N,L N,M/H C,L C,M/H S,L S,M/H
COND, sensitivity=3
200
600
N,L N,M/H C,L C,M/H S,L S,M/H


CONDHO, sensitivity=3
200
600
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DIC, sensitivity=3
20
40
60
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DOC, sensitivity=3
1
2
3
4
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
HCO3, sensitivity=3
1000
4000
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
IONSTR, sensitivity=3
0.000
0.010
0.020
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
K, sensitivity=3
0
100
250
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
MG, sensitivity=3
0
2000
4000
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
NA., sensitivity=3
0
500
1500
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
NH4, sensitivity=3
0.5
1.5
2.5
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H



NO3, sensitivity=3
0
40
80
NTL, sensitivity=3
0
500
1500
ORGION, sensitivity=3
10
20
30
40
PTL, sensitivity=3
0
50
150
SE, sensitivity=3
0.0
0.4
0.8
SO4, sensitivity=3
0
500
1500
SOBC, sensitivity=3
0
4000
8000
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


CONDHO, sensitivity=3
200
600
L
M/H
DIC, sensitivity=3
20
40
60
L
M/H
DOC, sensitivity=3
1
2
3
4
L
M/H
HCO3, sensitivity=3
1000
4000
L
M/H
IONSTR, sensitivity=3
0.000
0.010
0.020
L
M/H
K, sensitivity=3
0
100
250
L
M/H
MG, sensitivity=3
0
2000
4000
L
M/H
NA., sensitivity=3
0
500
1500
L
M/H
NH4, sensitivity=3
0.5
1.5
2.5
L
M/H


NO3, sensitivity=3
NTL, sensitivity=3
ORGION, sensitivity=3
PTL, sensitivity=3
SE, sensitivity=3
SO4, sensitivity=3
SOBC, sensitivity=3
L
M/H

G. Macroinvertebrate Metric Sensitivity

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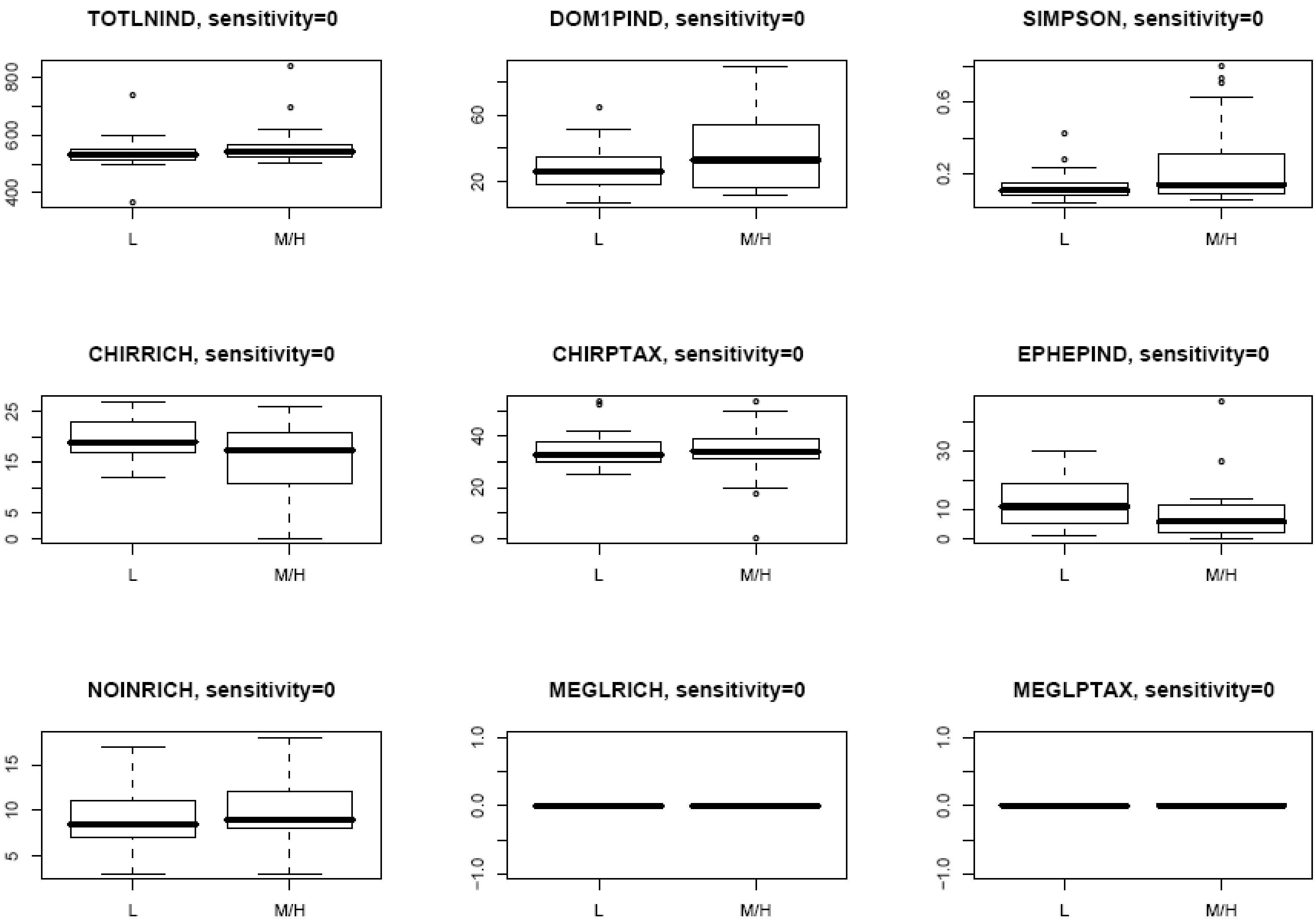
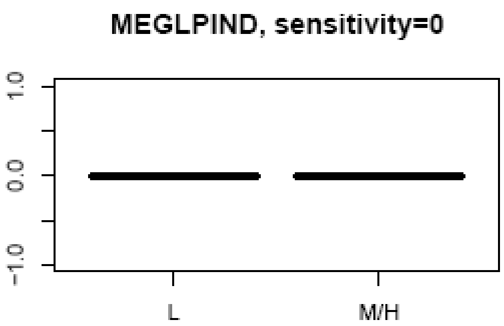
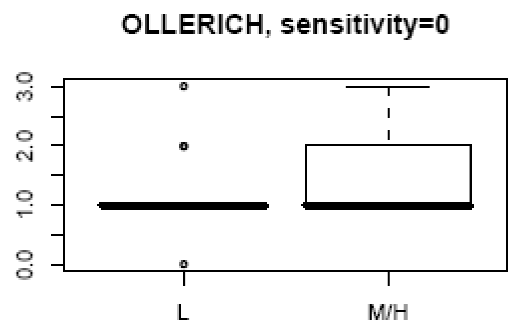
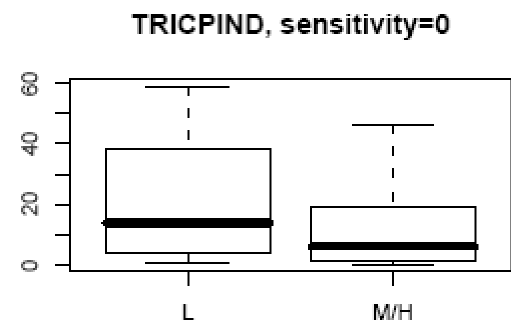
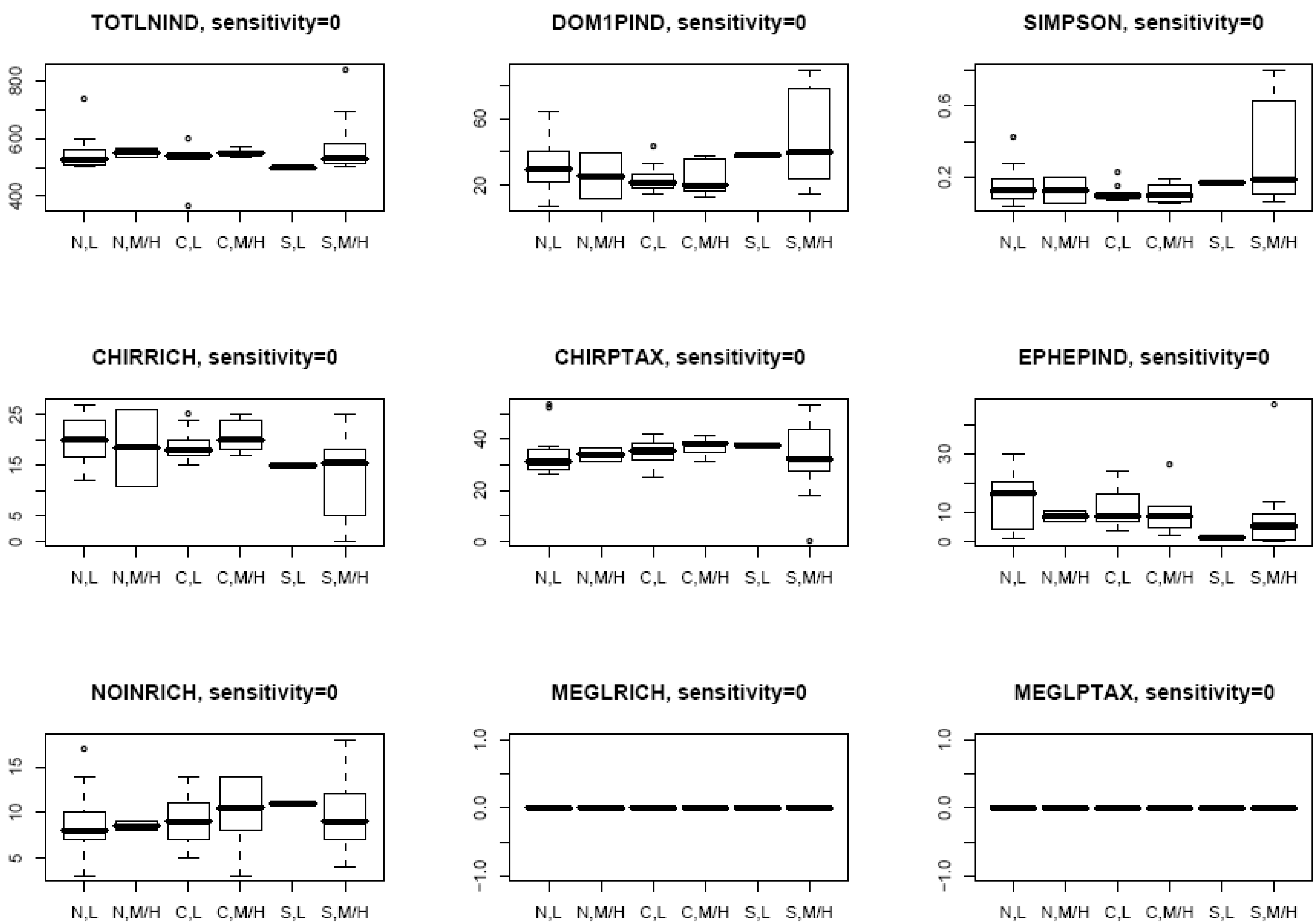
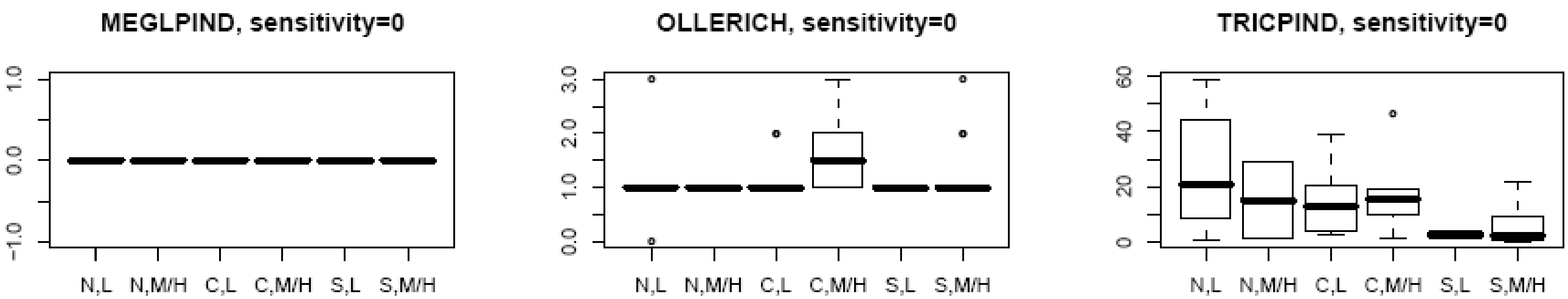

TOTLNIND, sensitivity=0
DOM1PIND, sensitivity=0
SIMPSON, sensitivity=0
CHIRRICH, sensitivity=0
CHIRPTAX, sensitivity=0
EPHEPIND, sensitivity=0
NOINRICH, sensitivity=0
MEGLRICH, sensitivity=0
MEGLPTAX, sensitivity=0
L
M/H

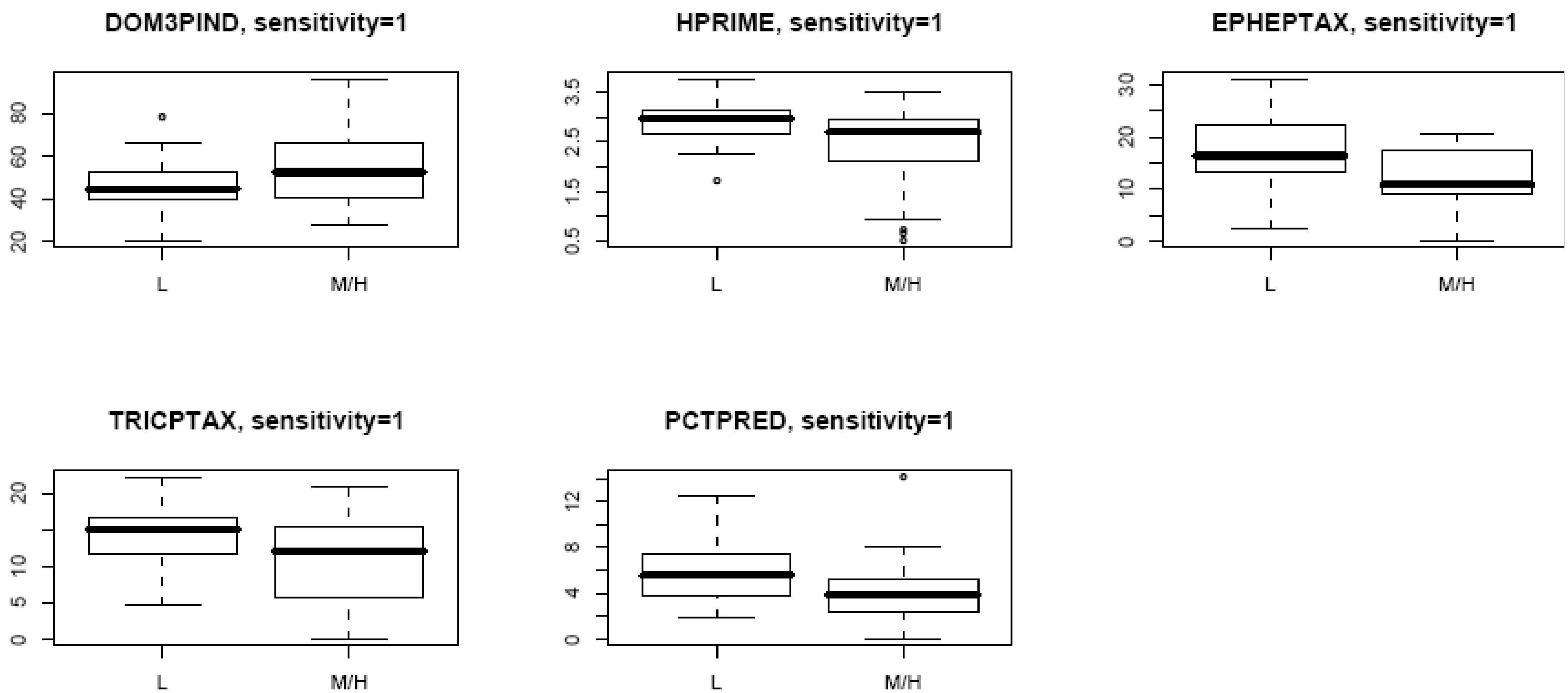

MEGLPIND, sensitivity=0
1.0
0.0
-1.0
L
M/H


OLLERICH, sensitivity=0
3.0
2.0
1.0
0.0
L
M/H

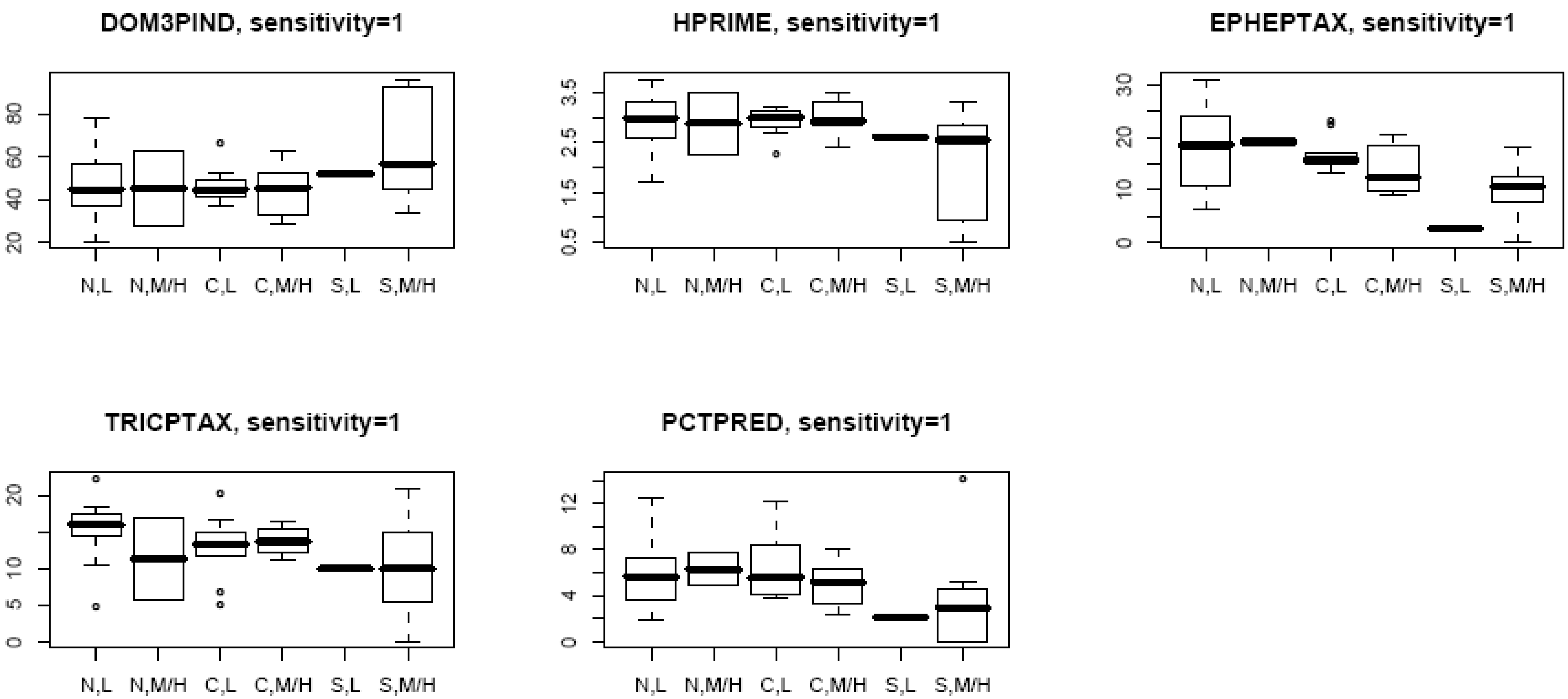

TRICPIND, sensitivity=0
60
40
20
0
L
M/H

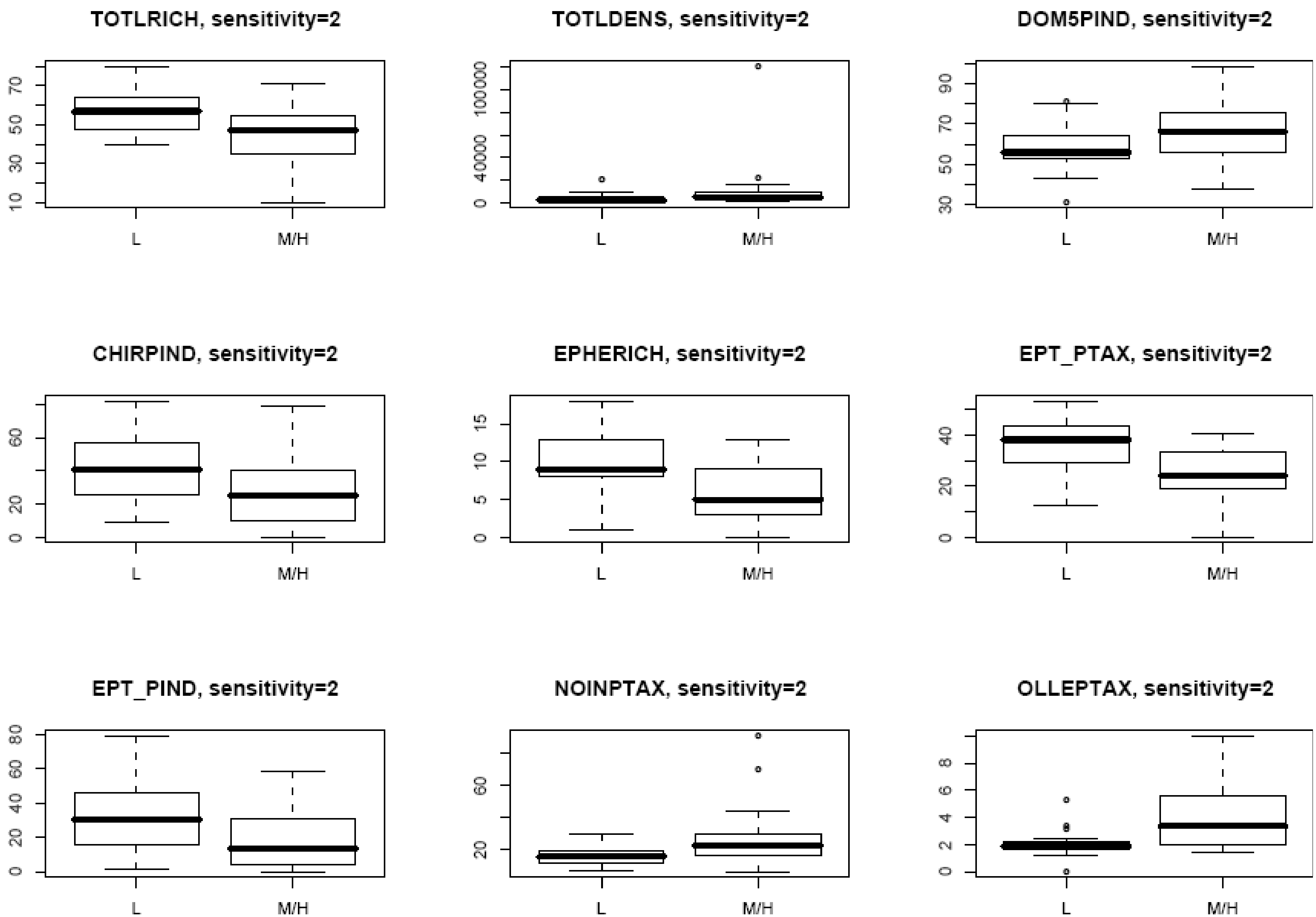

TOTLNIND, sensitivity=0
DOM1PIND, sensitivity=0
SIMPSON, sensitivity=0
CHIRRICH, sensitivity=0
CHIRPTAX, sensitivity=0
EPHEPIND, sensitivity=0
NOINRICH, sensitivity=0
MEGLRICH, sensitivity=0
MEGLPTAX, sensitivity=0
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

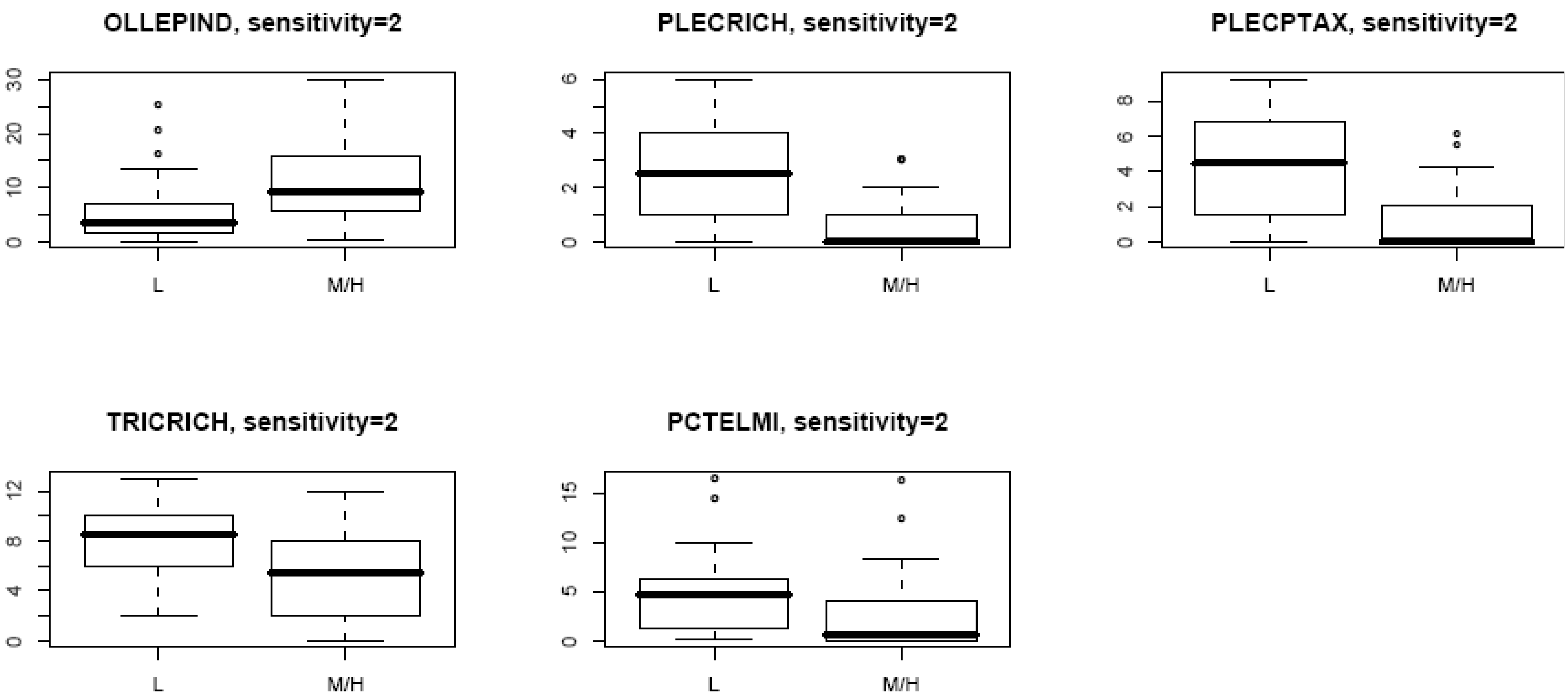

MEGLPIND, sensitivity=0
-1.0
0.0
1.0
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
OLLERICH, sensitivity=0
0.0
1.0
2.0
3.0
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
TRICPIND, sensitivity=0
0
20
40
60
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

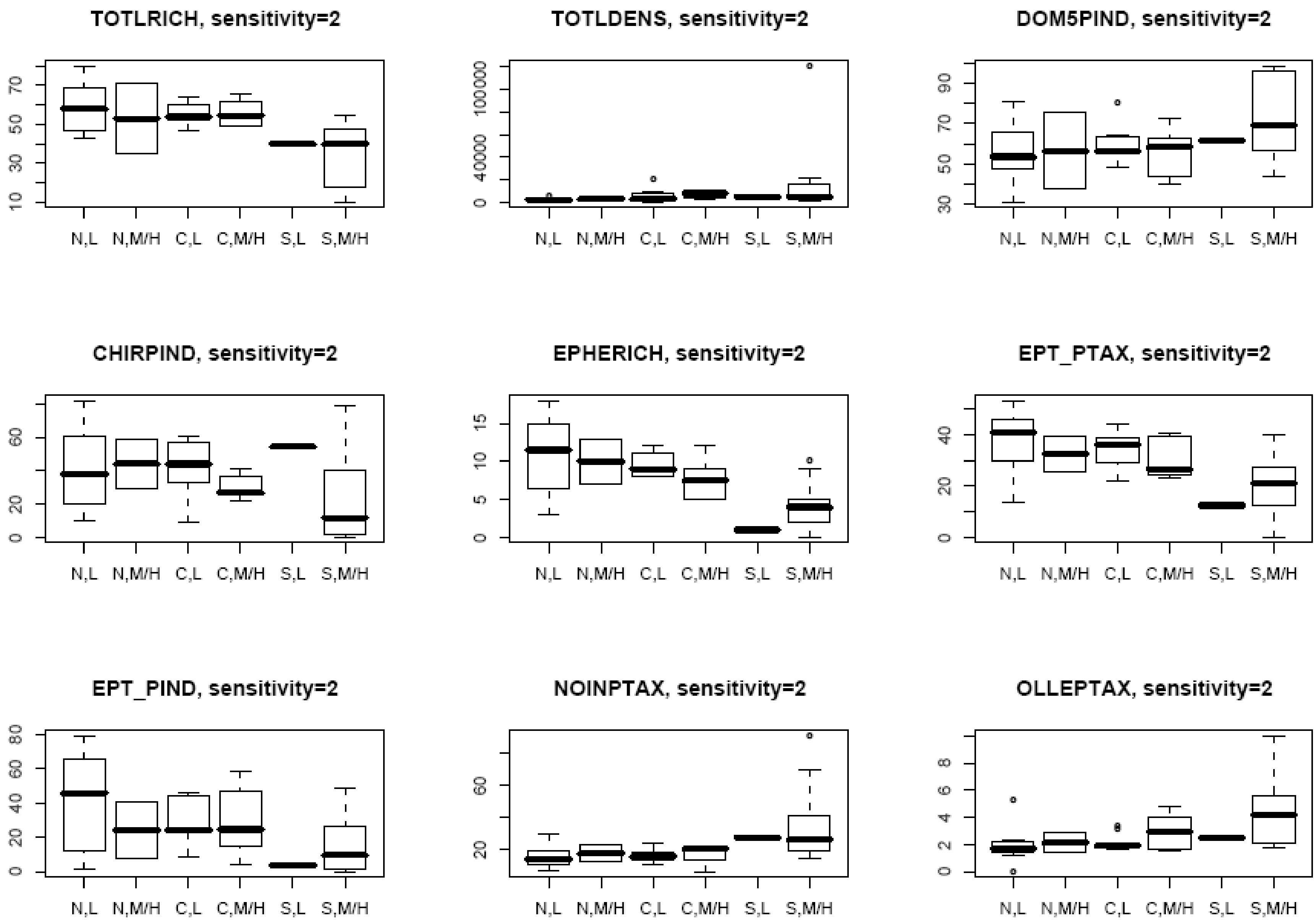


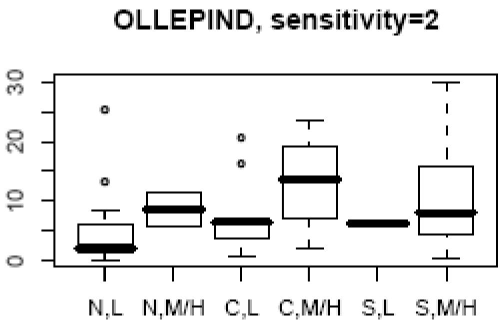
DOM3PIND, sensitivity=1
HPRIME, sensitivity=1
EPHEPTAX, sensitivity=1
TRICPTAX, sensitivity=1
PCTPRED, sensitivity=1
L
M/H

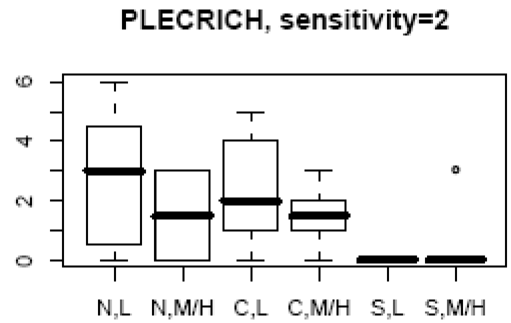

DOM3PIND, sensitivity=1
HPRIME, sensitivity=1
EPHEPTAX, sensitivity=1
TRICPTAX, sensitivity=1
PCTPRED, sensitivity=1
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

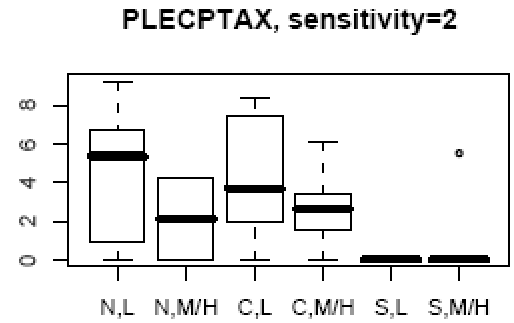

TOTLRICH, sensitivity=2
TOTLDENS, sensitivity=2
DOM5PIND, sensitivity=2
CHIRPIND, sensitivity=2
EPHERICH, sensitivity=2
EPT_PTAX, sensitivity=2
EPT_PIND, sensitivity=2
NOINPTAX, sensitivity=2
OLLEPTAX, sensitivity=2
L
M/H

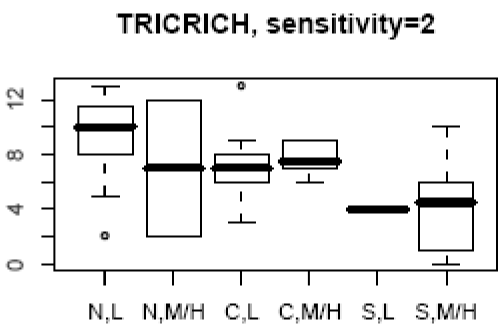

OLLEPIND, sensitivity=2
PLECRICH, sensitivity=2
PLECPTAX, sensitivity=2
TRICRICH, sensitivity=2
PCTELMI, sensitivity=2
L
M/H
0
10
20
30
2
4
6
8
12
5
15

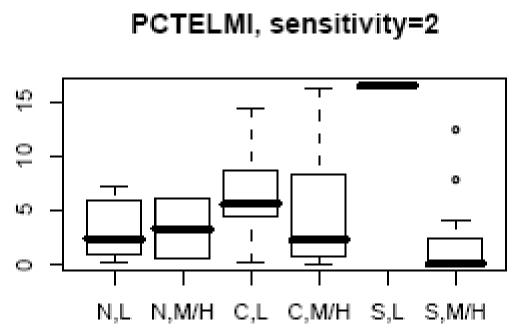

TOTLRICH, sensitivity=2
10
30
50
70
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
TOTLDENS, sensitivity=2
0
40000
100000
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
DOM5PIND, sensitivity=2
30
50
70
90
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
CHIRPIND, sensitivity=2
0
20
60
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
EPHERICH, sensitivity=2
0
5
10
15
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
EPT_PTAX, sensitivity=2
0
20
40
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
EPT_PIND, sensitivity=2
0
20
40
60
80
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
NOINPTAX, sensitivity=2
20
60
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H
OLLEPTAX, sensitivity=2
0
2
4
6
8
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H

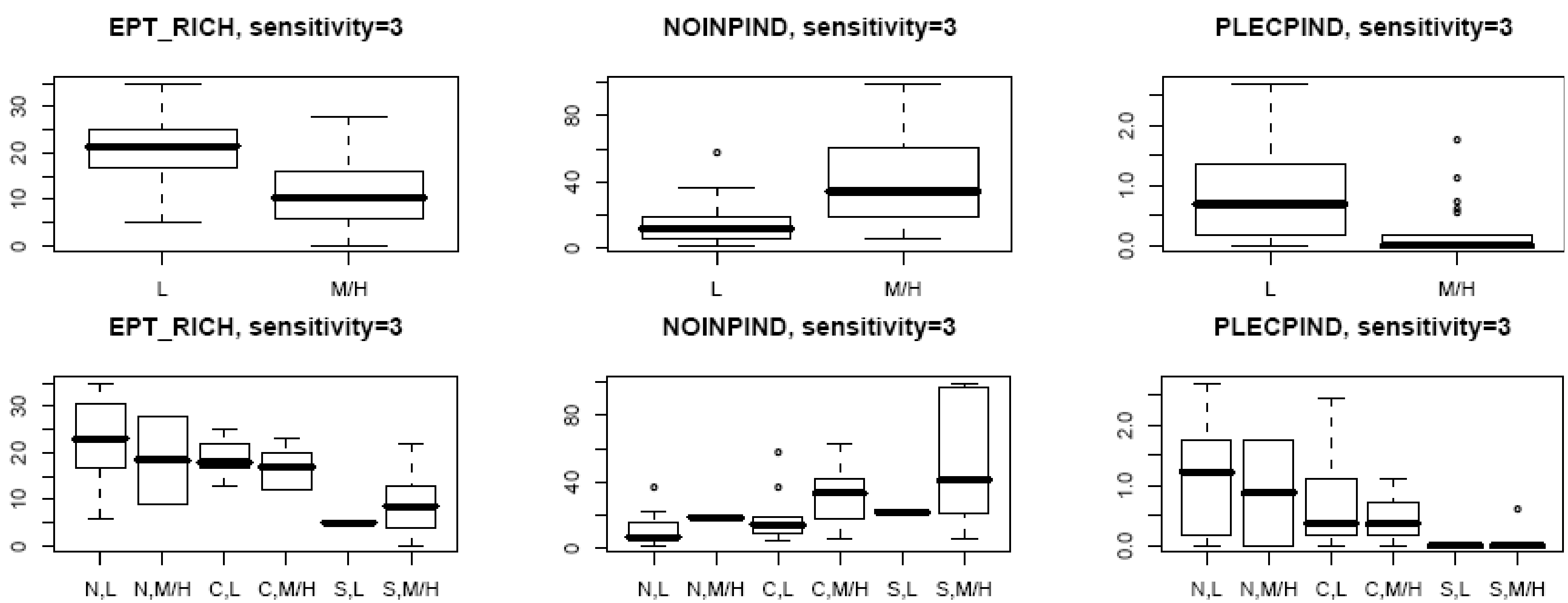

OLLEPIND, sensitivity=2
0
10
20
30
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


PLECRICH, sensitivity=2
0
2
4
6
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


PLECPTAX, sensitivity=2
0
2
4
6
8
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


TRICRICH, sensitivity=2
0
4
8
12
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


PCTELMI, sensitivity=2
0
5
10
15
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H


EPT_RICH, sensitivity=3
NOINPIND, sensitivity=3
PLECPIND, sensitivity=3
0
10
20
30
0
40
80
0.0
1.0
2.0
L
M/H
EPT_RICH, sensitivity=3
NOINPIND, sensitivity=3
PLECPIND, sensitivity=3
N,L
N,M/H
C,L
C,M/H
S,L
S,M/H